US009370954B2

(12) **United States Patent**
Sasayama

(10) **Patent No.: US 9,370,954 B2**
(45) **Date of Patent: Jun. 21, 2016**

(54) **METHOD FOR MEASURING AMOUNT OF POSITIONAL DEVIATION AND IMAGE-RECORDING DEVICE**

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(72) Inventor: **Hiroyuki Sasayama**, Kanagawa (JP)

(73) Assignee: **FUJIFILM Corporation**, Tokyo (JP)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **14/824,944**

(22) Filed: **Aug. 12, 2015**

(65) **Prior Publication Data**

US 2015/0343820 A1 Dec. 3, 2015

Related U.S. Application Data

(63) Continuation of application No. PCT/JP2014/054370, filed on Feb. 24, 2014.

(30) **Foreign Application Priority Data**

Mar. 15, 2013 (JP) 2013-053226

(51) **Int. Cl.**
B41J 2/21 (2006.01)
B41J 29/393 (2006.01)

(52) **U.S. Cl.**
CPC ***B41J 29/393*** (2013.01); ***B41J 2/2135*** (2013.01); ***B41J 2/2146*** (2013.01); *B41J 2/2142* (2013.01); *B41J 2029/3935* (2013.01)

(58) **Field of Classification Search**
CPC B41J 2/2146
USPC 347/13
See application file for complete search history.

(56) **References Cited**

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* cited by examiner

Primary Examiner — Shelby Fidler
(74) *Attorney, Agent, or Firm* — Studebaker & Brackett PC

(57) **ABSTRACT**

Dot patterns are recorded on a recording medium at intervals determined in advance in a second direction using first and second head modules while relatively moving a recording head and the recording medium in the second direction. The dot patterns are optically read, and a density profile representing change in density in the second direction of a read image of the dot patterns is calculated. A repetition period of a waveform corresponding to each dot pattern in the density profile is calculated, and data of the density profile is integrated and averaged in each repetition period to calculate an integrated density profile. A peak position of a waveform corresponding to each dot pattern in the integrated density profile is obtained, and the amount of positional deviation is calculated based on each peak position.

18 Claims, 29 Drawing Sheets

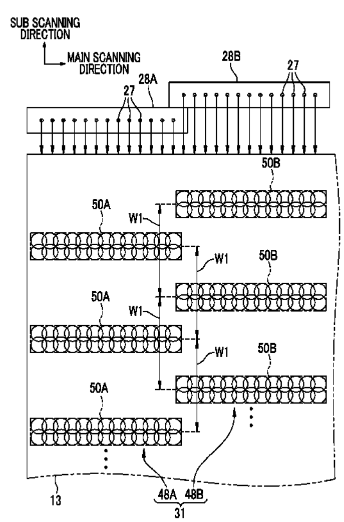


FIG. 1

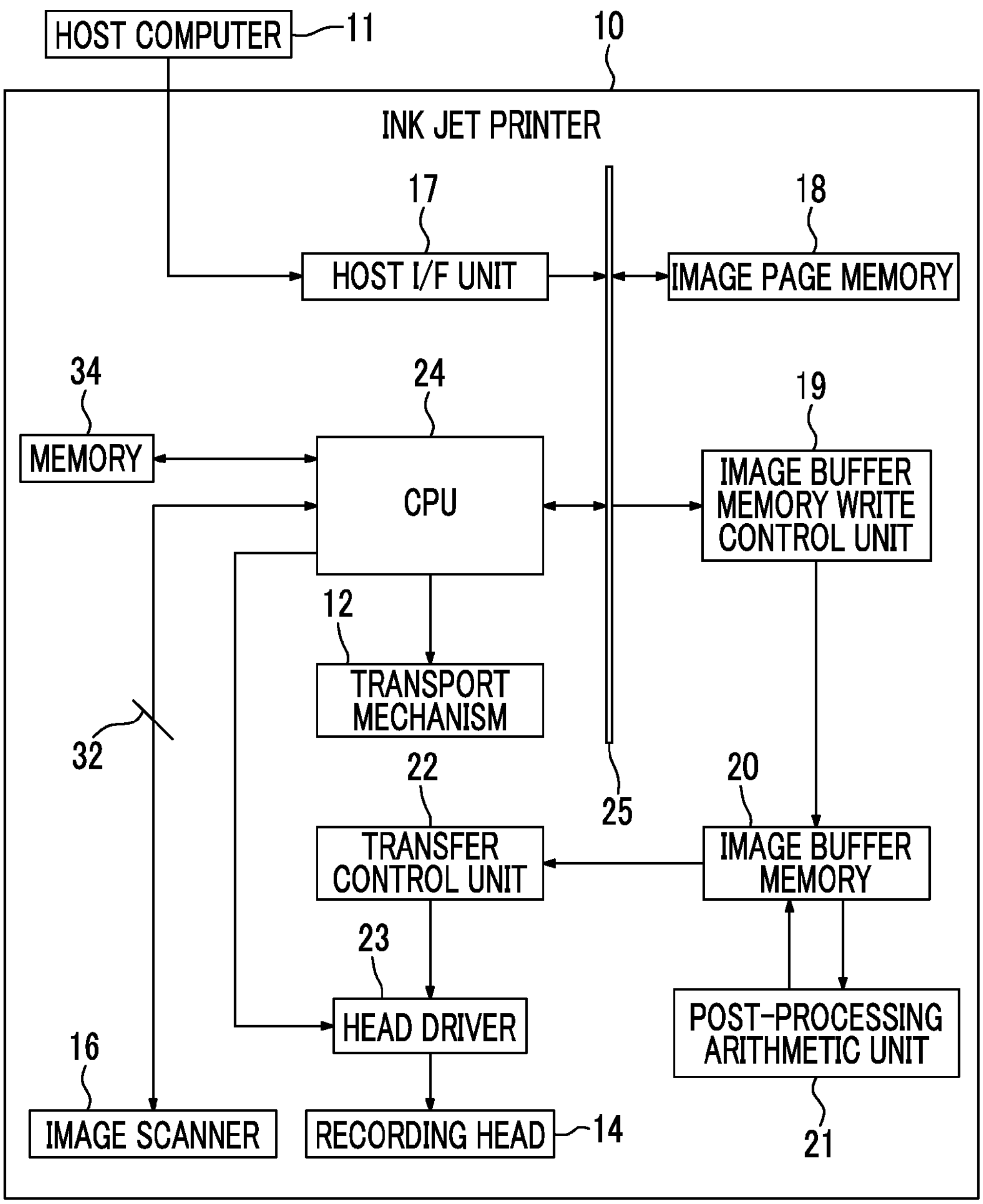

HOST COMPUTER
11
10
INK JET PRINTER
17
18
HOST I/F UNIT
IMAGE PAGE MEMORY
34
24
19
MEMORY
CPU
IMAGE BUFFER MEMORY WRITE CONTROL UNIT
12
TRANSPORT MECHANISM
32
22
25
20
TRANSFER CONTROL UNIT
IMAGE BUFFER MEMORY
23
HEAD DRIVER
POST-PROCESSING ARITHMETIC UNIT
16
IMAGE SCANNER
RECORDING HEAD
14
21

FIG. 2

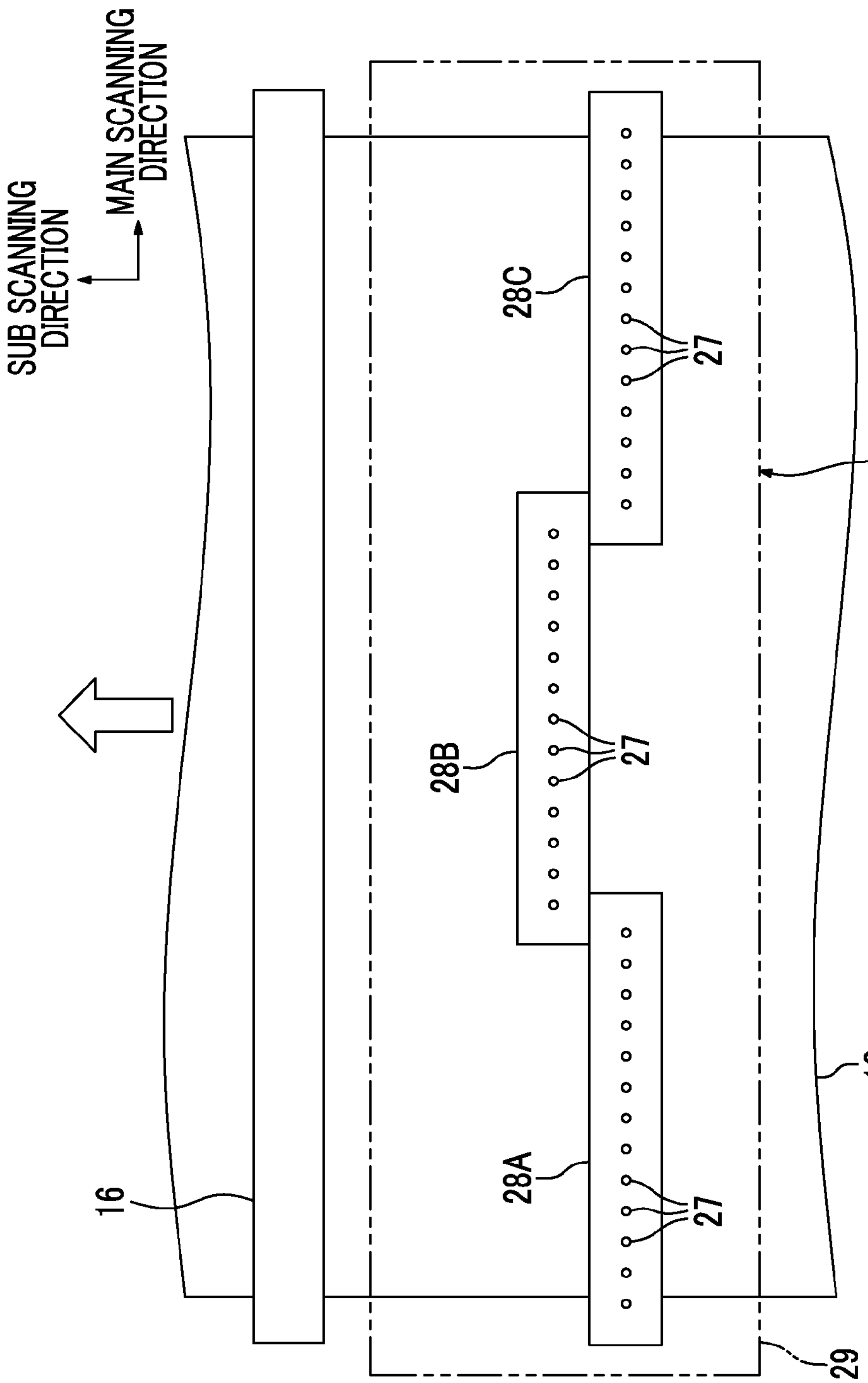

SUB SCANNING DIRECTION
MAIN SCANNING DIRECTION
28C
27
14
28B
27
28A
27
16
13
29

FIG. 3

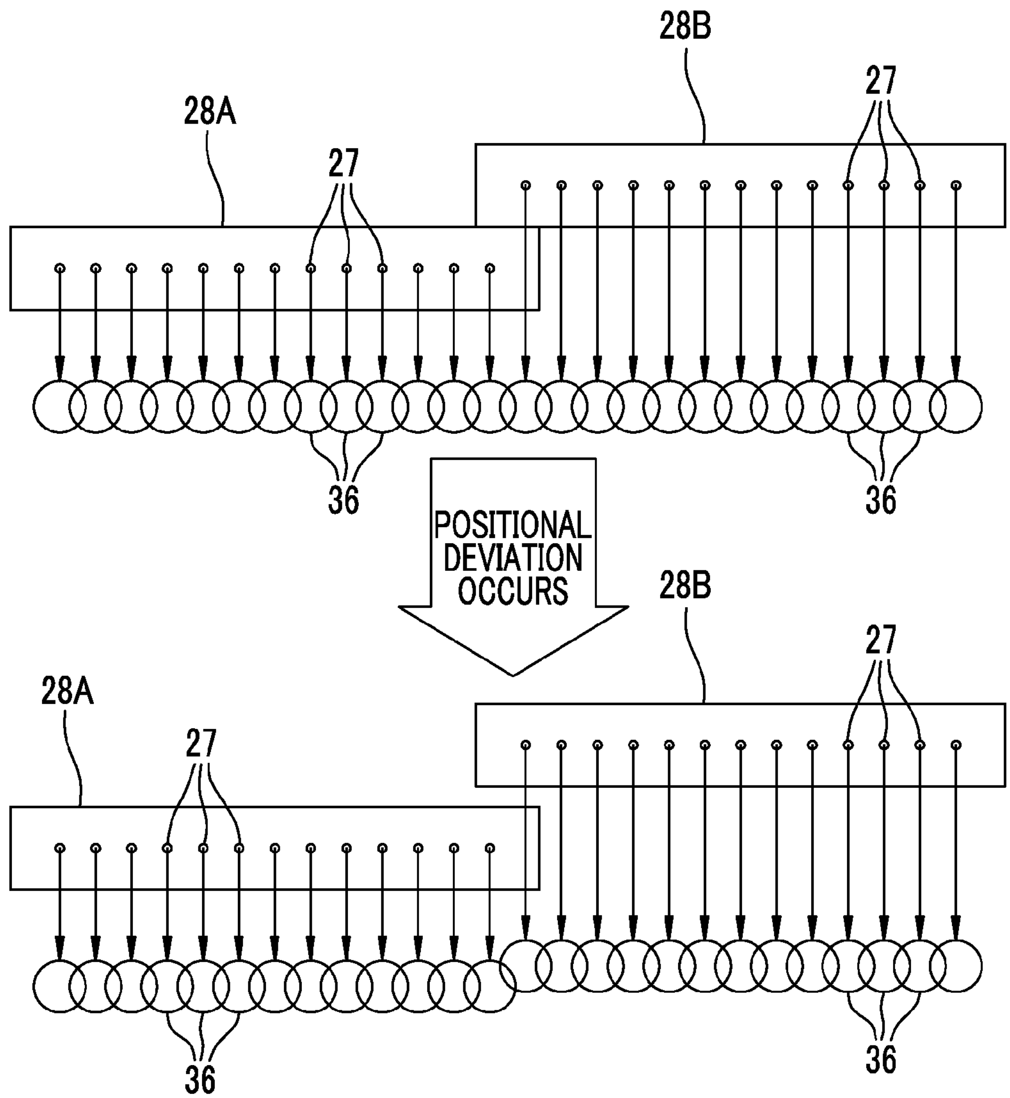
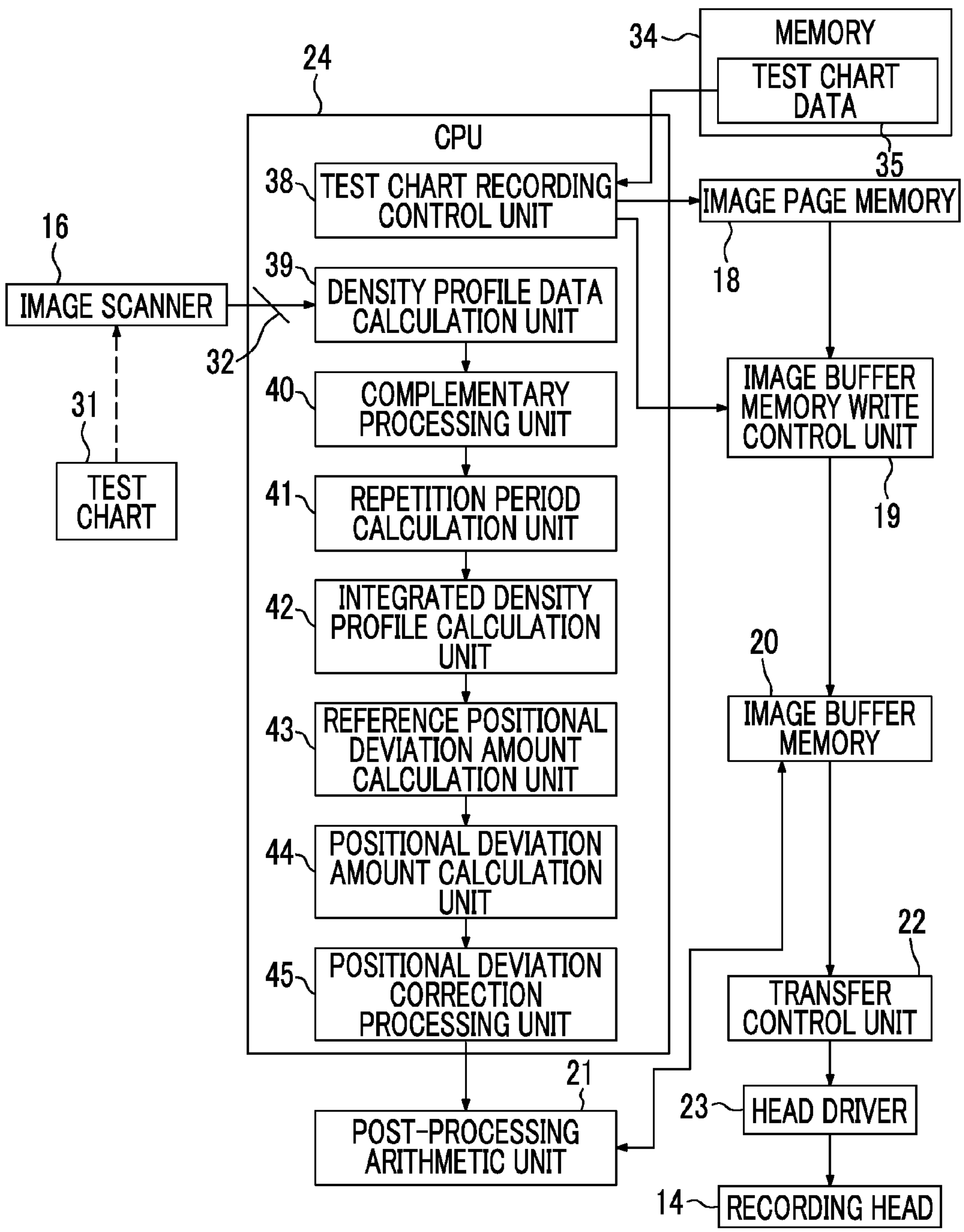

28B
27
28A
27
36
36
POSITIONAL
DEVIATION
OCCURS
28B
27
28A
27
36
36

FIG. 4



34
MEMORY
TEST CHART DATA
35
24
CPU
38
TEST CHART RECORDING CONTROL UNIT
IMAGE PAGE MEMORY
18
16
IMAGE SCANNER
39
DENSITY PROFILE DATA CALCULATION UNIT
32
31
TEST CHART
40
COMPLEMENTARY PROCESSING UNIT
IMAGE BUFFER MEMORY WRITE CONTROL UNIT
19
41
REPETITION PERIOD CALCULATION UNIT
42
INTEGRATED DENSITY PROFILE CALCULATION UNIT
20
IMAGE BUFFER MEMORY
43
REFERENCE POSITIONAL DEVIATION AMOUNT CALCULATION UNIT
44
POSITIONAL DEVIATION AMOUNT CALCULATION UNIT
22
45
POSITIONAL DEVIATION CORRECTION PROCESSING UNIT
TRANSFER CONTROL UNIT
21
23
HEAD DRIVER
POST-PROCESSING ARITHMETIC UNIT
14
RECORDING HEAD

FIG. 5

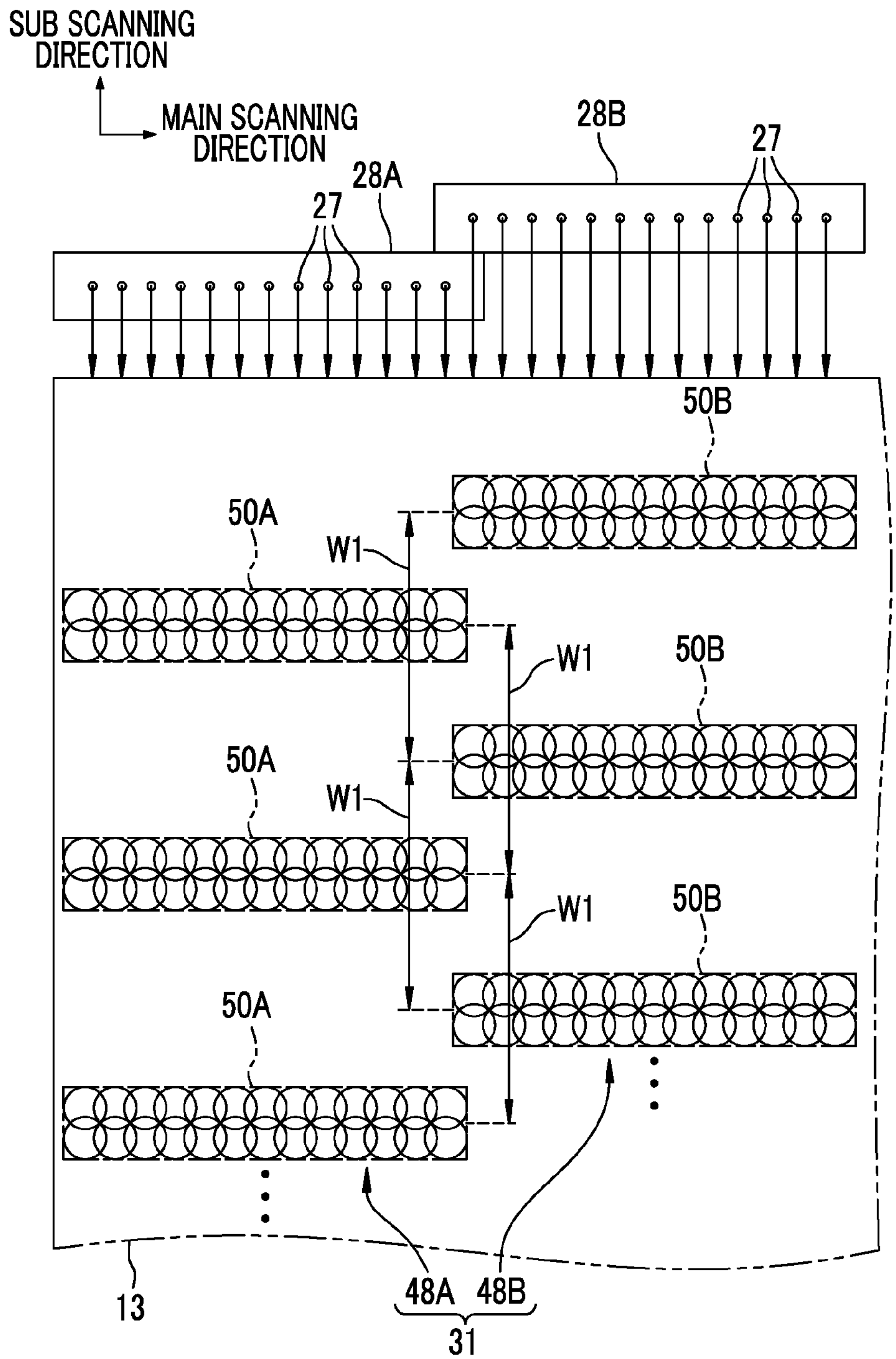

SUB SCANNING DIRECTION
MAIN SCANNING DIRECTION
28B
27
28A
27
50B
50A
W1
W1
50B
50A
W1
W1
50B
50A
13
48A
48B
31

FIG. 6A

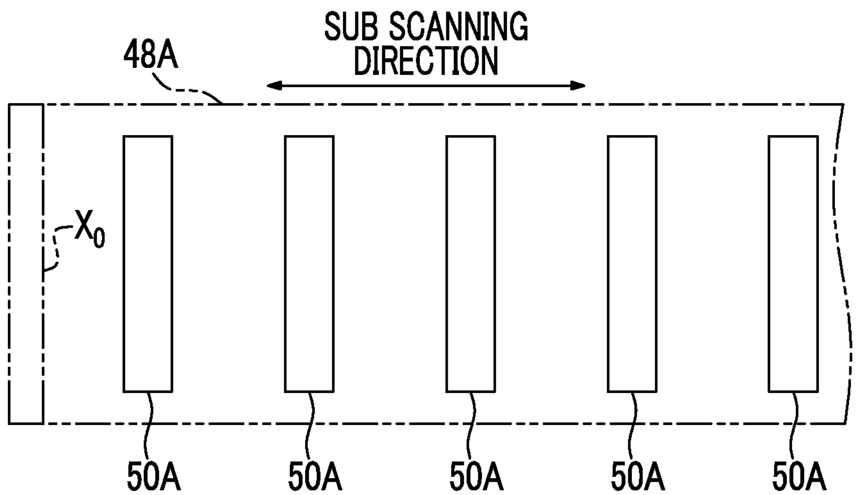


FIG. 6B

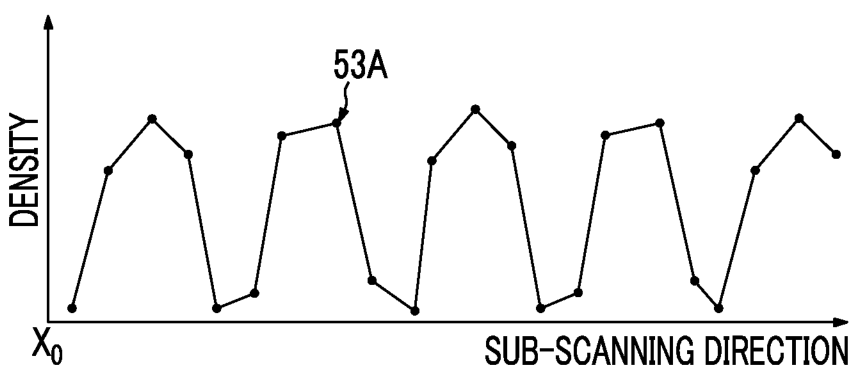


FIG. 6C

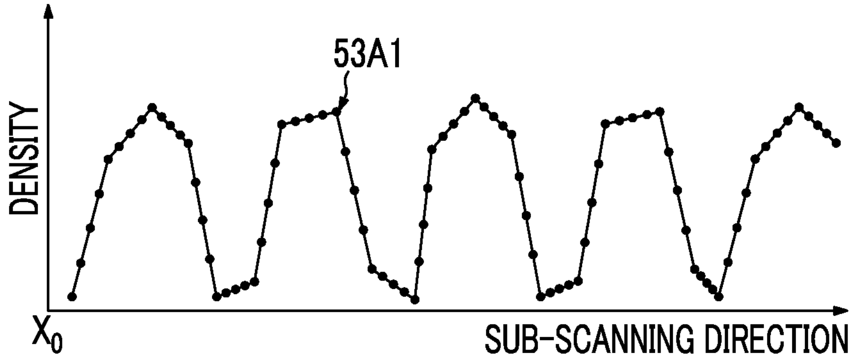


FIG. 7A

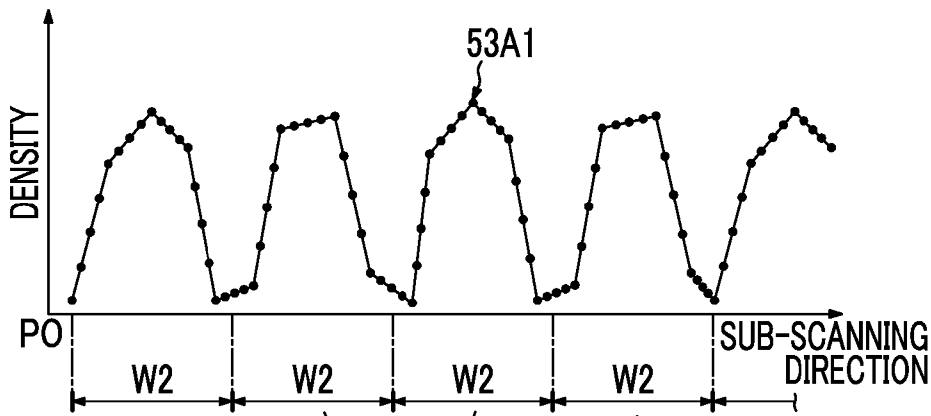


FIG. 7B

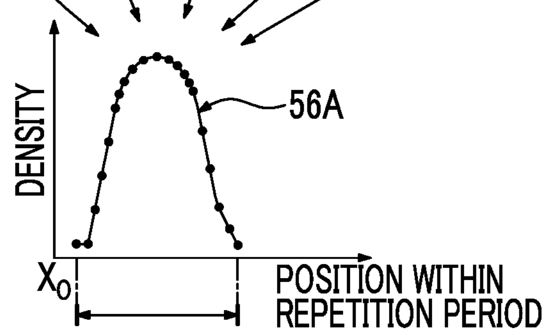


FIG. 7C

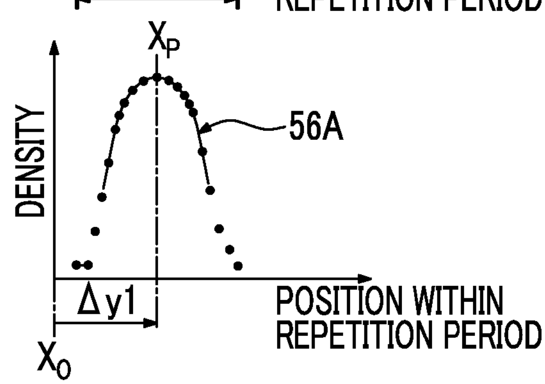


FIG. 8

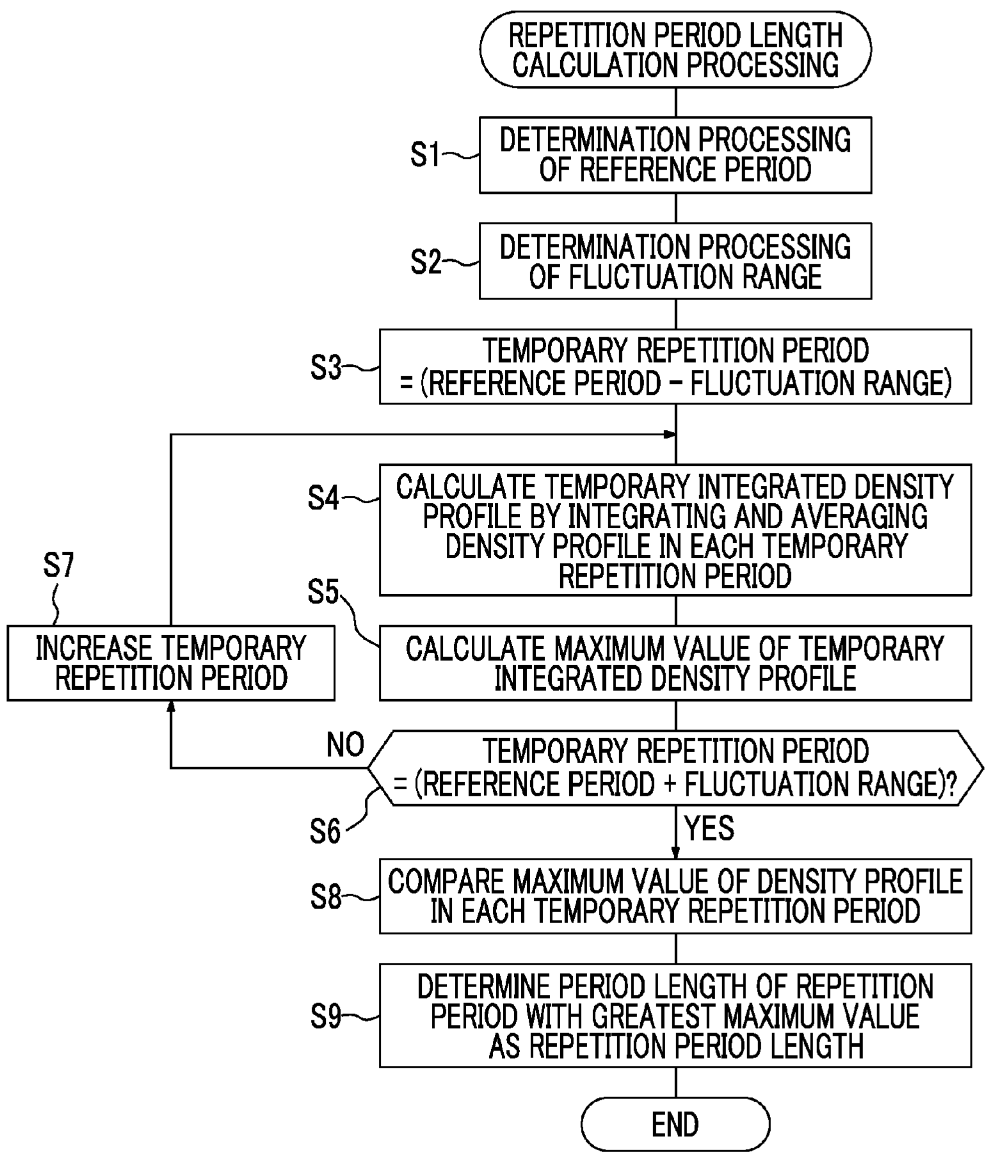

REPETITION PERIOD LENGTH CALCULATION PROCESSING
S1
DETERMINATION PROCESSING OF REFERENCE PERIOD
S2
DETERMINATION PROCESSING OF FLUCTUATION RANGE
S3
TEMPORARY REPETITION PERIOD = (REFERENCE PERIOD − FLUCTUATION RANGE)
S4
CALCULATE TEMPORARY INTEGRATED DENSITY PROFILE BY INTEGRATING AND AVERAGING DENSITY PROFILE IN EACH TEMPORARY REPETITION PERIOD
S5
CALCULATE MAXIMUM VALUE OF TEMPORARY INTEGRATED DENSITY PROFILE
S7
INCREASE TEMPORARY REPETITION PERIOD
NO
TEMPORARY REPETITION PERIOD = (REFERENCE PERIOD + FLUCTUATION RANGE)?
S6
YES
S8
COMPARE MAXIMUM VALUE OF DENSITY PROFILE IN EACH TEMPORARY REPETITION PERIOD
S9
DETERMINE PERIOD LENGTH OF REPETITION PERIOD WITH GREATEST MAXIMUM VALUE AS REPETITION PERIOD LENGTH
END

FIG. 9

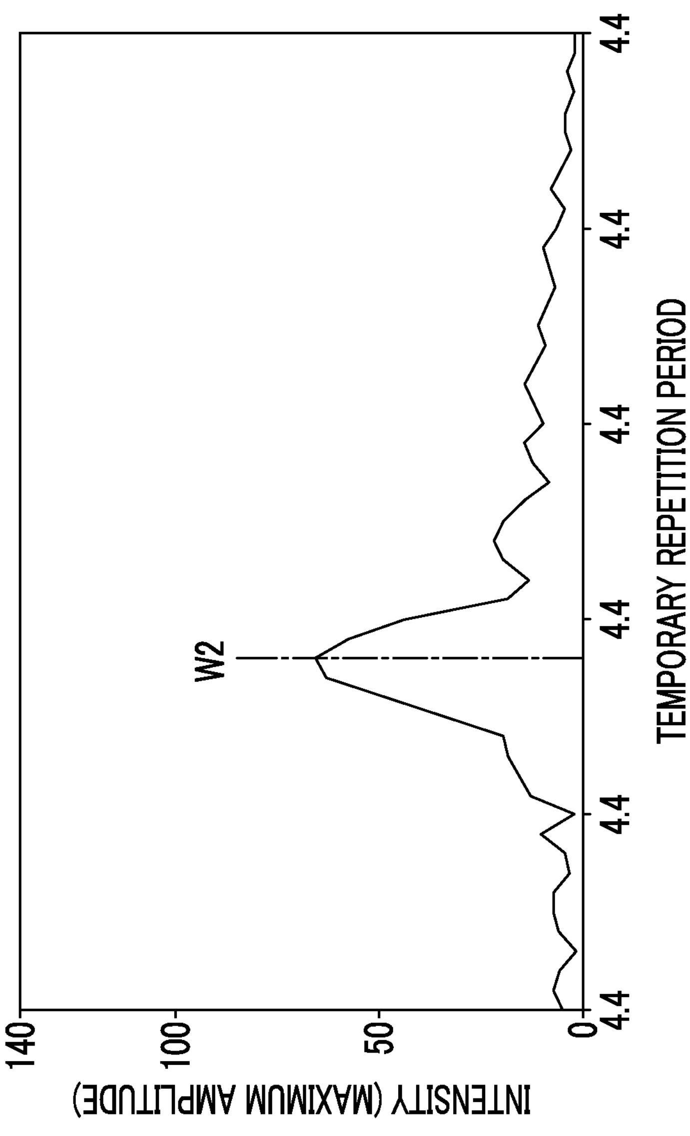

W2
INTENSITY (MAXIMUM AMPLITUDE)
140
100
50
0
4.4
4.4
4.4
4.4
4.4
4.4
TEMPORARY REPETITION PERIOD

FIG. 10

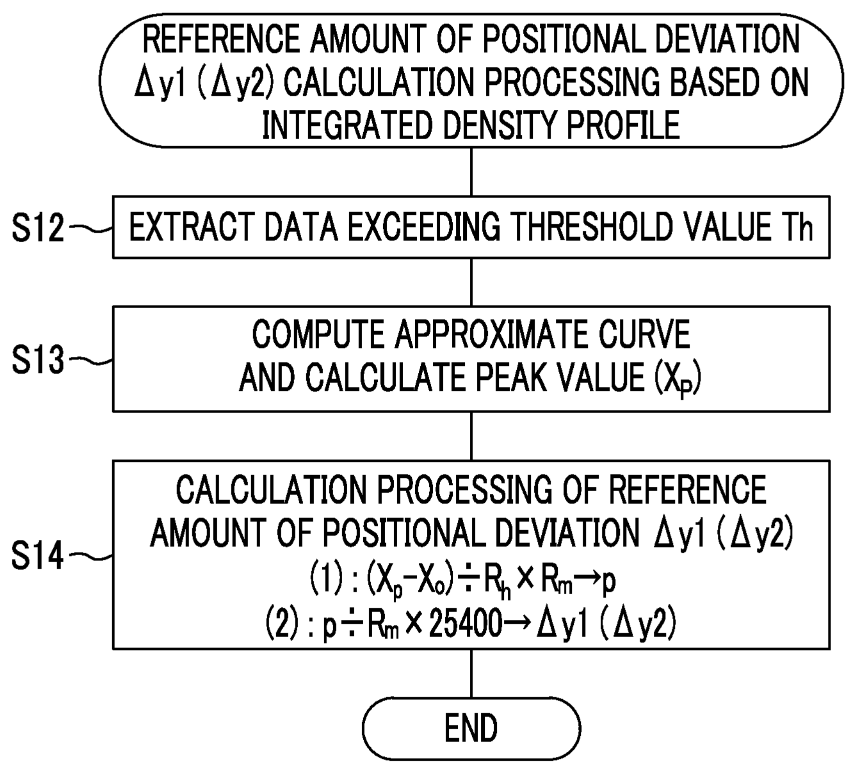
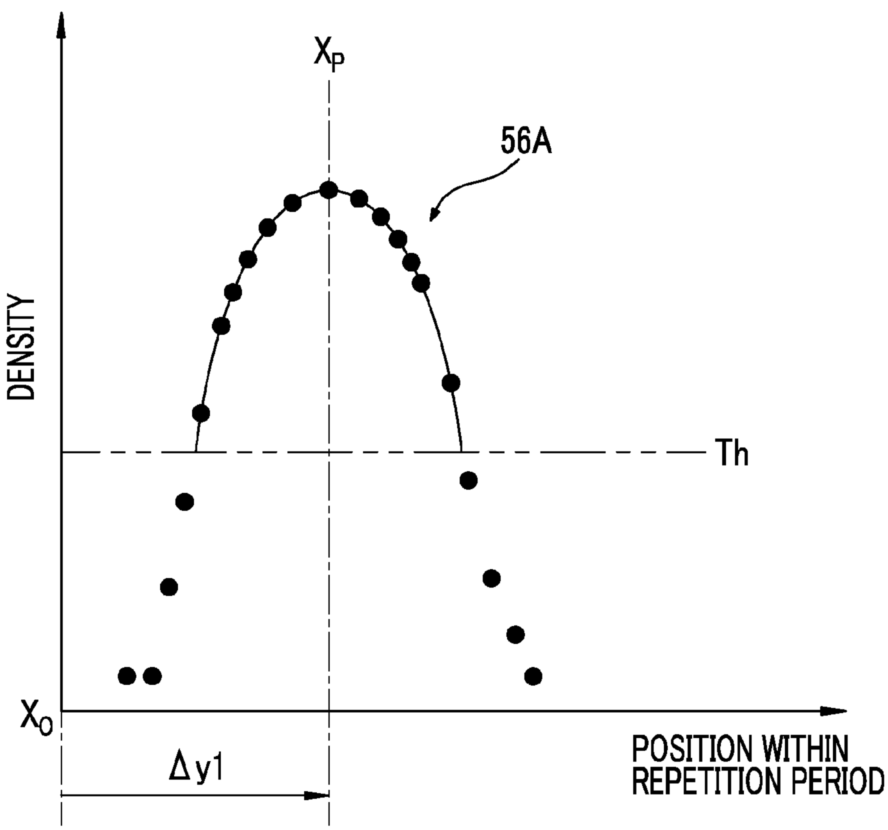

REFERENCE AMOUNT OF POSITIONAL DEVIATION
Δy1 (Δy2) CALCULATION PROCESSING BASED ON
INTEGRATED DENSITY PROFILE
S12
EXTRACT DATA EXCEEDING THRESHOLD VALUE Th
S13
COMPUTE APPROXIMATE CURVE
AND CALCULATE PEAK VALUE (X_p)
S14
CALCULATION PROCESSING OF REFERENCE
AMOUNT OF POSITIONAL DEVIATION Δy1 (Δy2)
(1) : $(X_p-X_o) \div R_h \times R_m \rightarrow p$
(2) : $p \div R_m \times 25400 \rightarrow \Delta y1\ (\Delta y2)$
END

FIG. 11



X_P
56A
DENSITY
Th
X_0
$\Delta y1$
POSITION WITHIN REPETITION PERIOD

FIG. 12

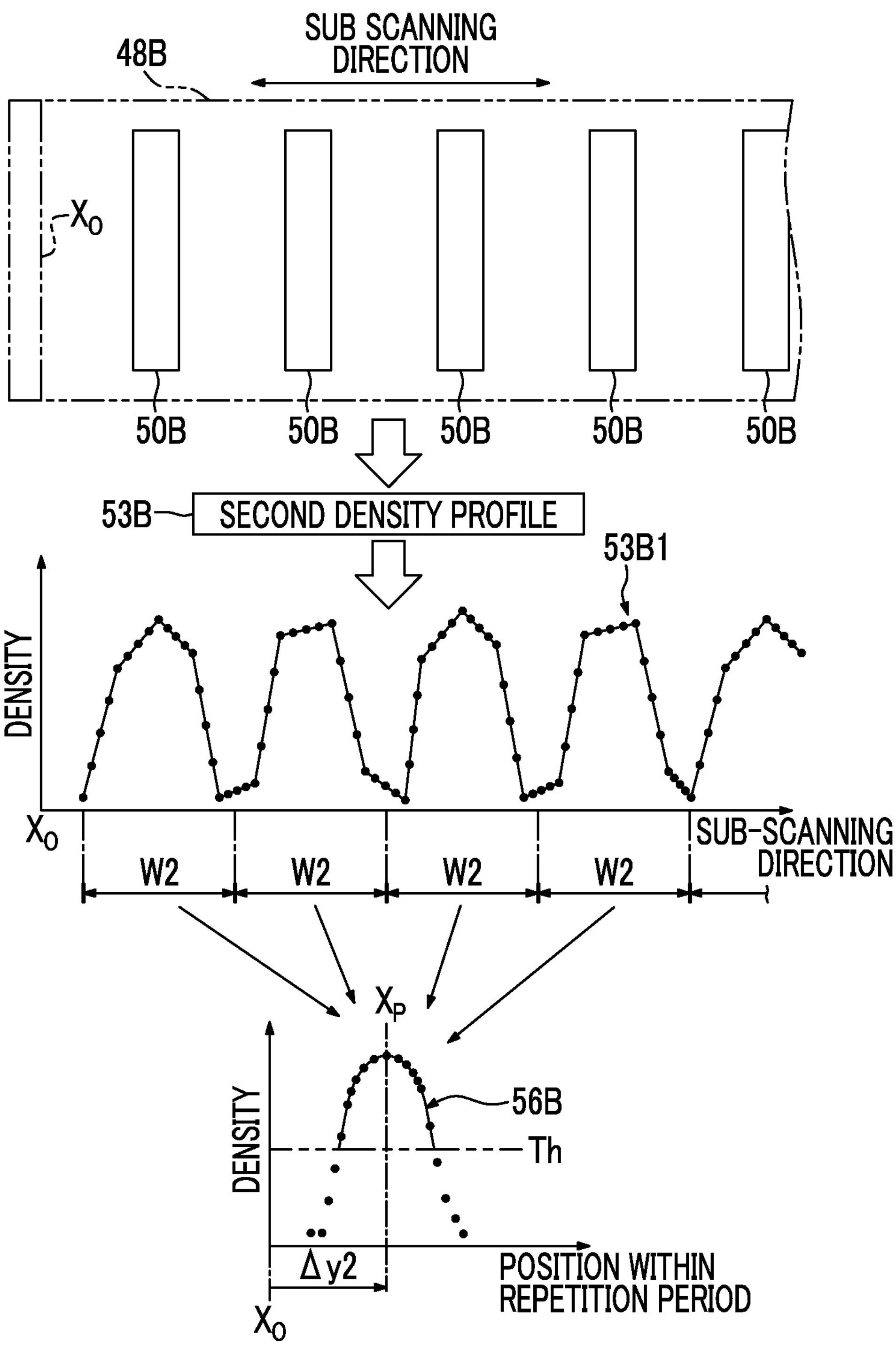
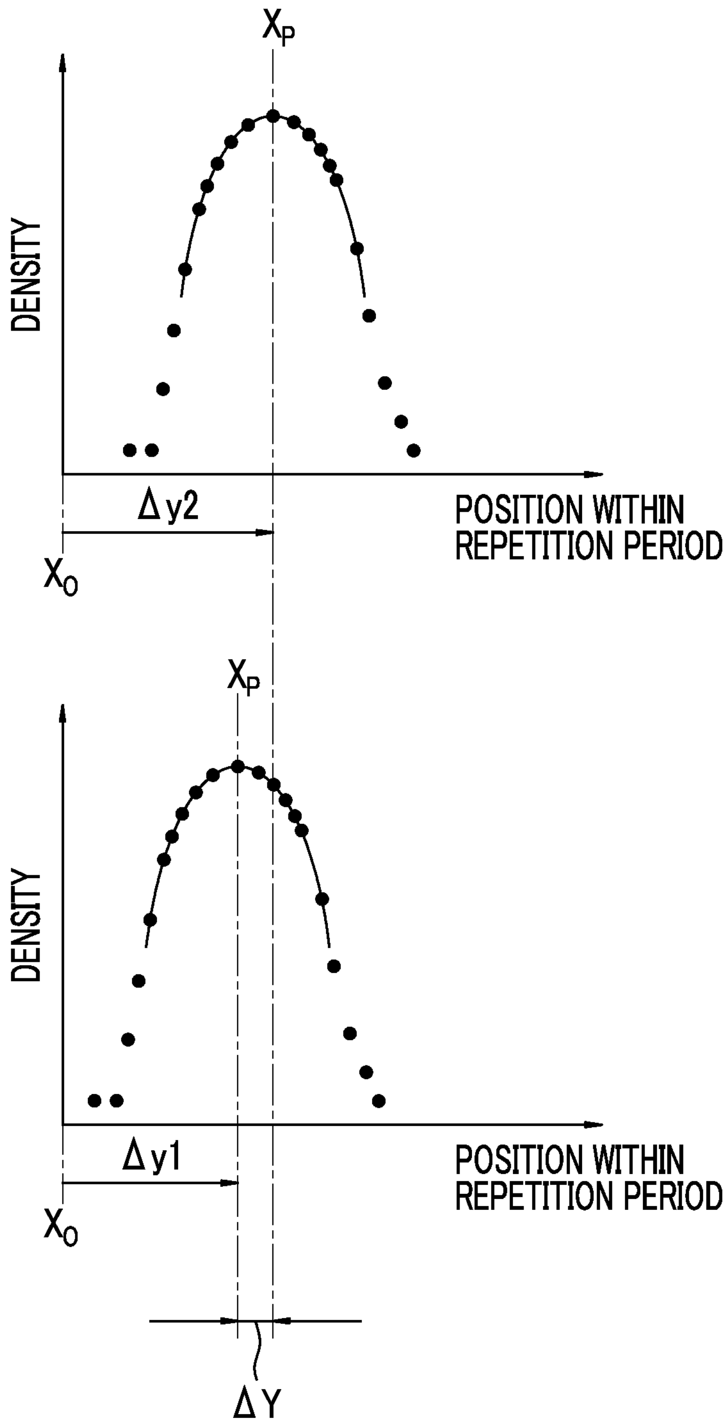

SUB SCANNING DIRECTION
48B
X_0
50B
50B
50B
50B
50B
53B
SECOND DENSITY PROFILE
53B1
DENSITY
X_0
SUB-SCANNING DIRECTION
W2
W2
W2
W2
X_P
DENSITY
56B
Th
$\Delta y2$
POSITION WITHIN REPETITION PERIOD
X_0

FIG. 13



X_P
DENSITY
$\Delta y2$
POSITION WITHIN REPETITION PERIOD
X_0
X_P
DENSITY
$\Delta y1$
POSITION WITHIN REPETITION PERIOD
X_0
ΔY

FIG. 14

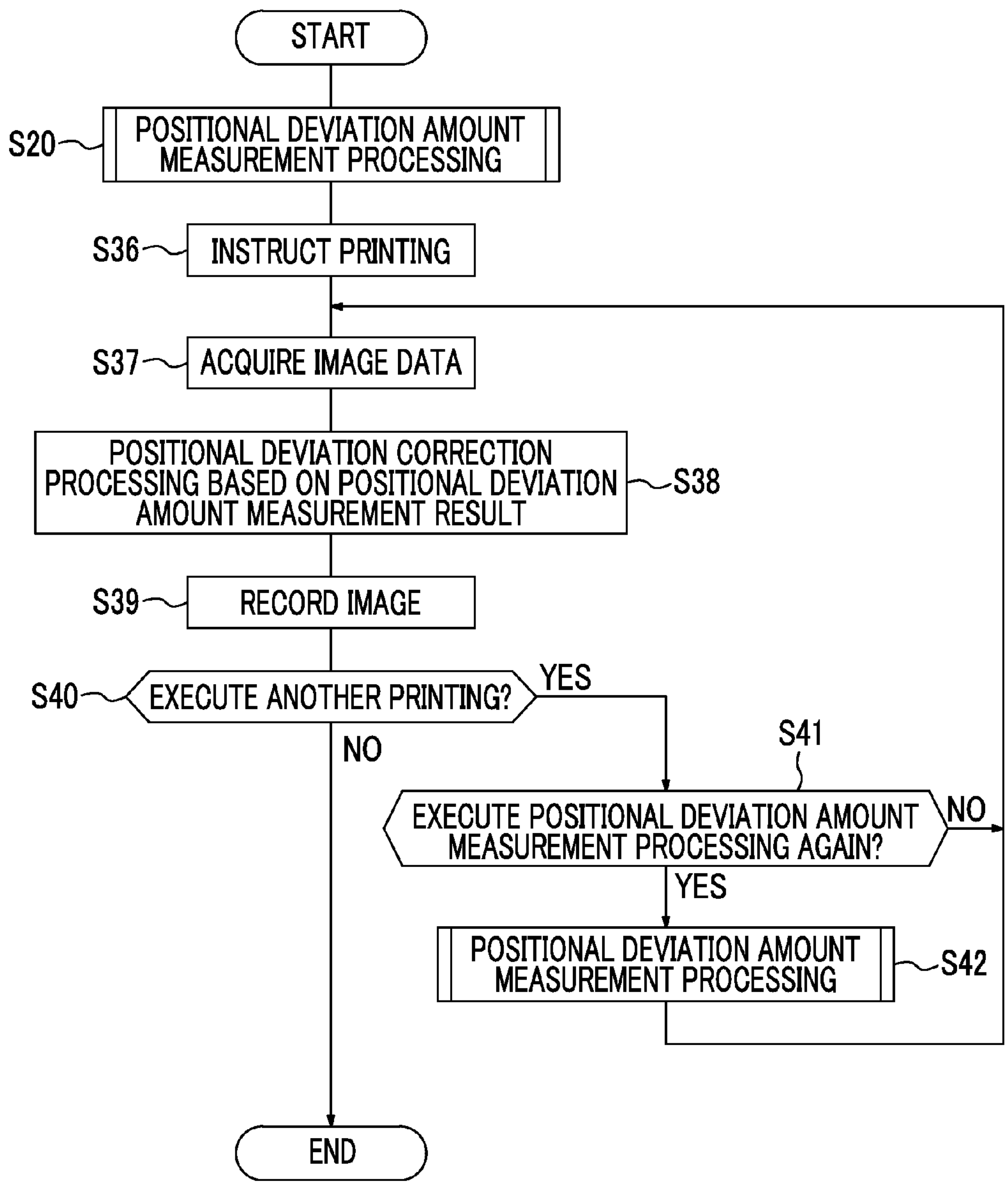

START
S20
POSITIONAL DEVIATION AMOUNT MEASUREMENT PROCESSING
S36
INSTRUCT PRINTING
S37
ACQUIRE IMAGE DATA
POSITIONAL DEVIATION CORRECTION PROCESSING BASED ON POSITIONAL DEVIATION AMOUNT MEASUREMENT RESULT
S38
S39
RECORD IMAGE
S40
EXECUTE ANOTHER PRINTING?
YES
NO
S41
EXECUTE POSITIONAL DEVIATION AMOUNT MEASUREMENT PROCESSING AGAIN?
NO
YES
POSITIONAL DEVIATION AMOUNT MEASUREMENT PROCESSING
S42
END

FIG. 15

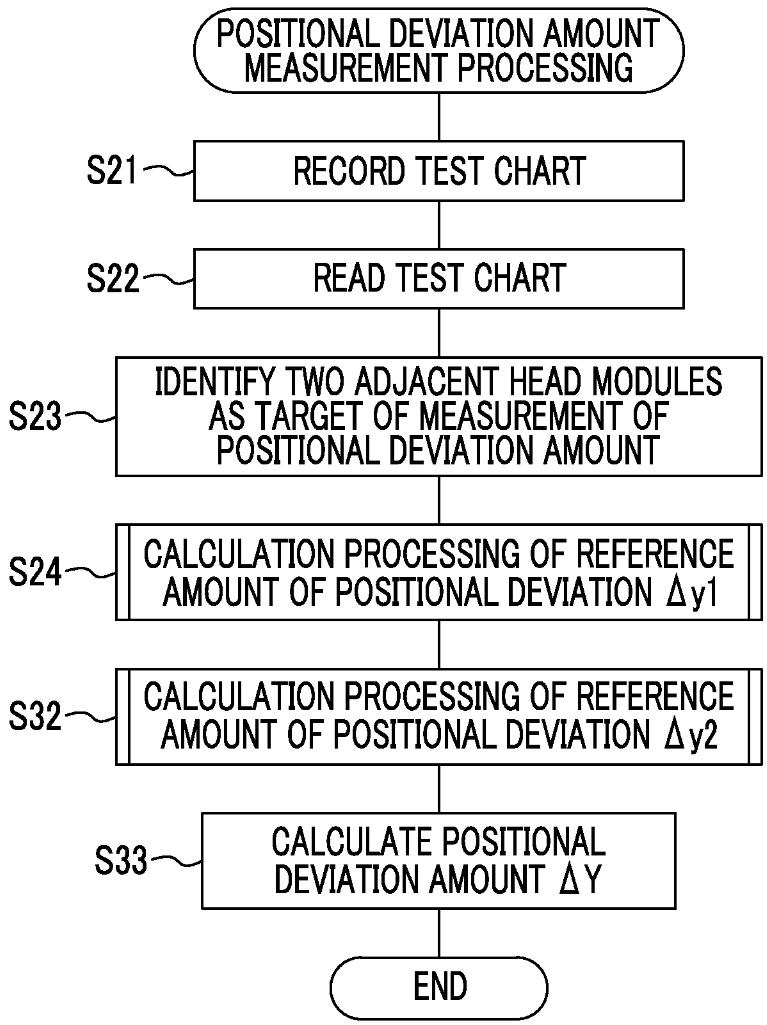

POSITIONAL DEVIATION AMOUNT MEASUREMENT PROCESSING
S21
RECORD TEST CHART
S22
READ TEST CHART
S23
IDENTIFY TWO ADJACENT HEAD MODULES AS TARGET OF MEASUREMENT OF POSITIONAL DEVIATION AMOUNT
S24
CALCULATION PROCESSING OF REFERENCE AMOUNT OF POSITIONAL DEVIATION Δy1
S32
CALCULATION PROCESSING OF REFERENCE AMOUNT OF POSITIONAL DEVIATION Δy2
S33
CALCULATE POSITIONAL DEVIATION AMOUNT ΔY
END

FIG. 16

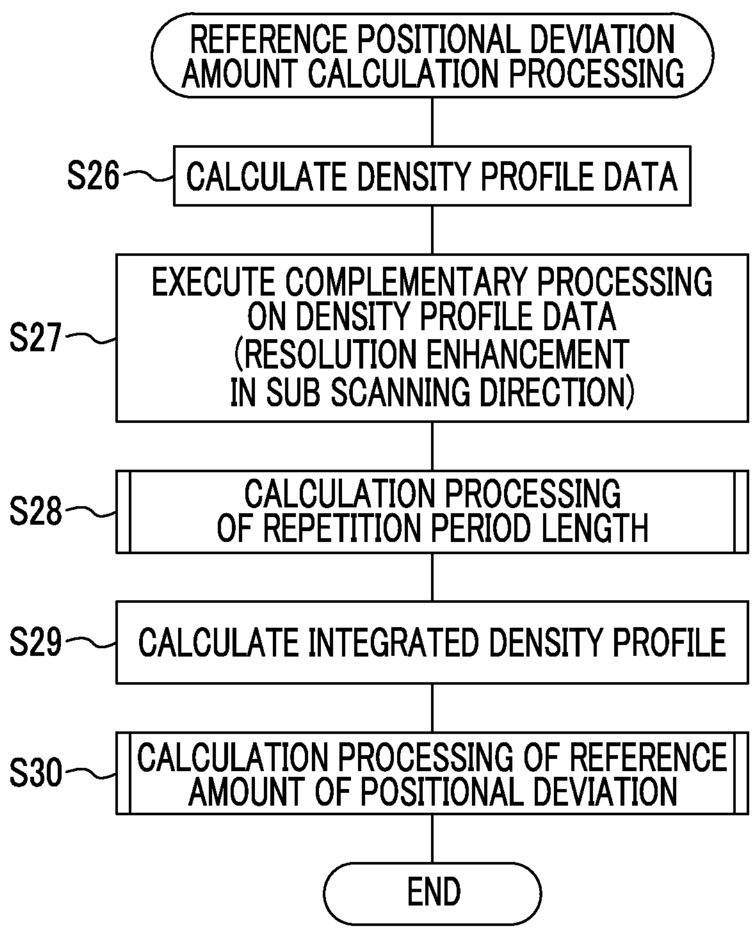

REFERENCE POSITIONAL DEVIATION AMOUNT CALCULATION PROCESSING
S26
CALCULATE DENSITY PROFILE DATA
S27
EXECUTE COMPLEMENTARY PROCESSING ON DENSITY PROFILE DATA (RESOLUTION ENHANCEMENT IN SUB SCANNING DIRECTION)
S28
CALCULATION PROCESSING OF REPETITION PERIOD LENGTH
S29
CALCULATE INTEGRATED DENSITY PROFILE
S30
CALCULATION PROCESSING OF REFERENCE AMOUNT OF POSITIONAL DEVIATION
END

FIG. 17

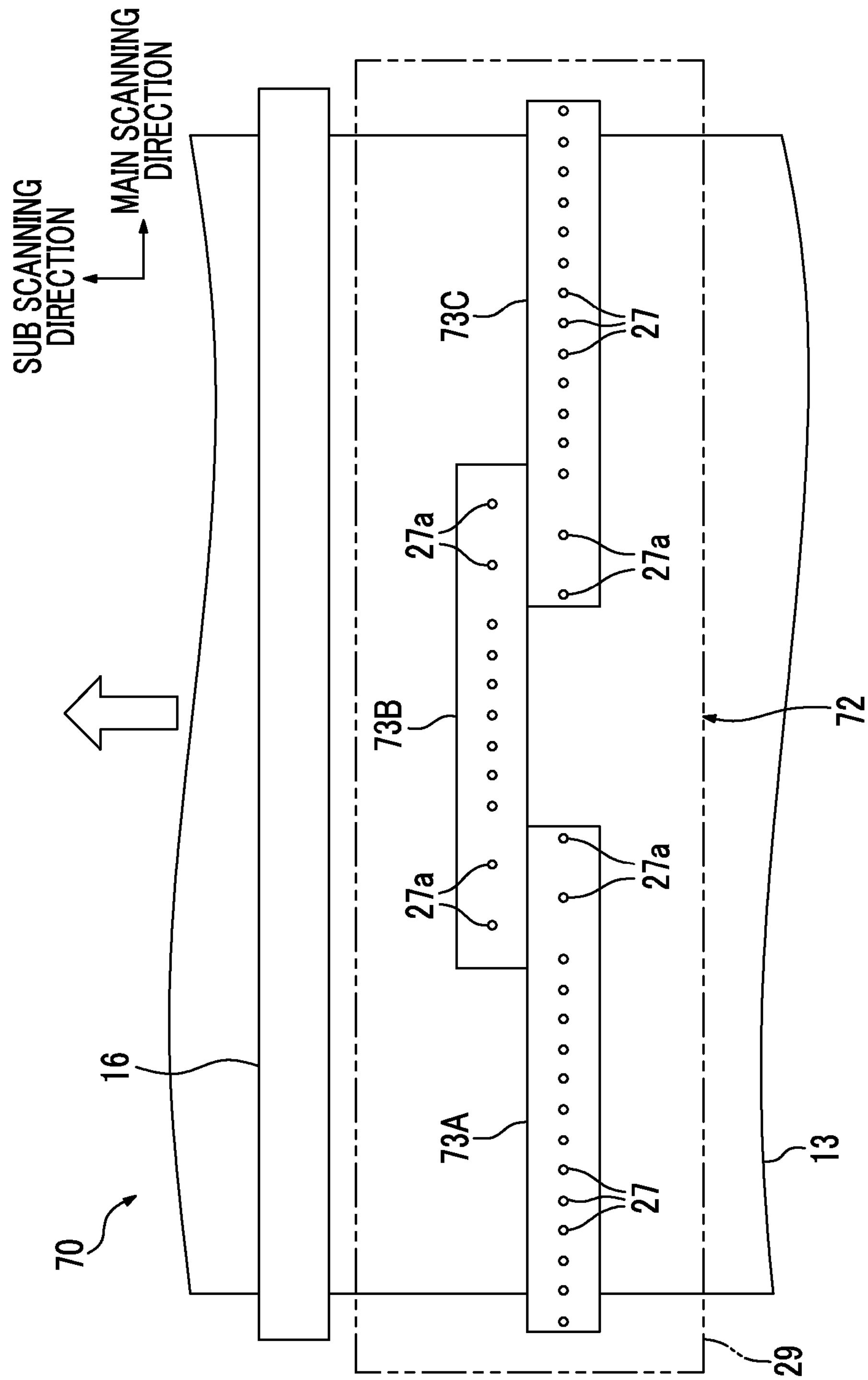
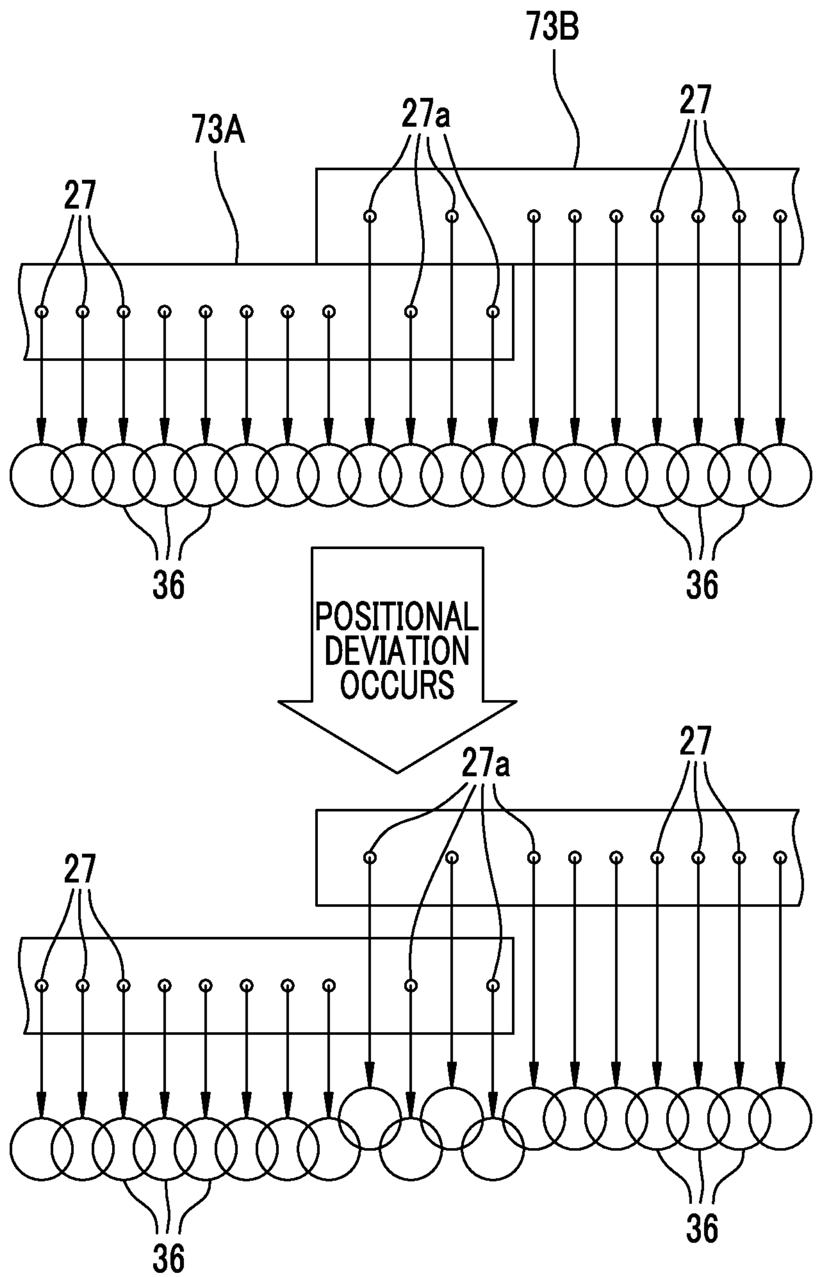

SUB SCANNING DIRECTION
MAIN SCANNING DIRECTION
73C
27
27a
27a
73B
72
27a
27a
16
73A
27
70
13
29

FIG. 18



73B
27a
27
73A
27
36
36
POSITIONAL
DEVIATION
OCCURS
27a
27
27
36
36

FIG. 19

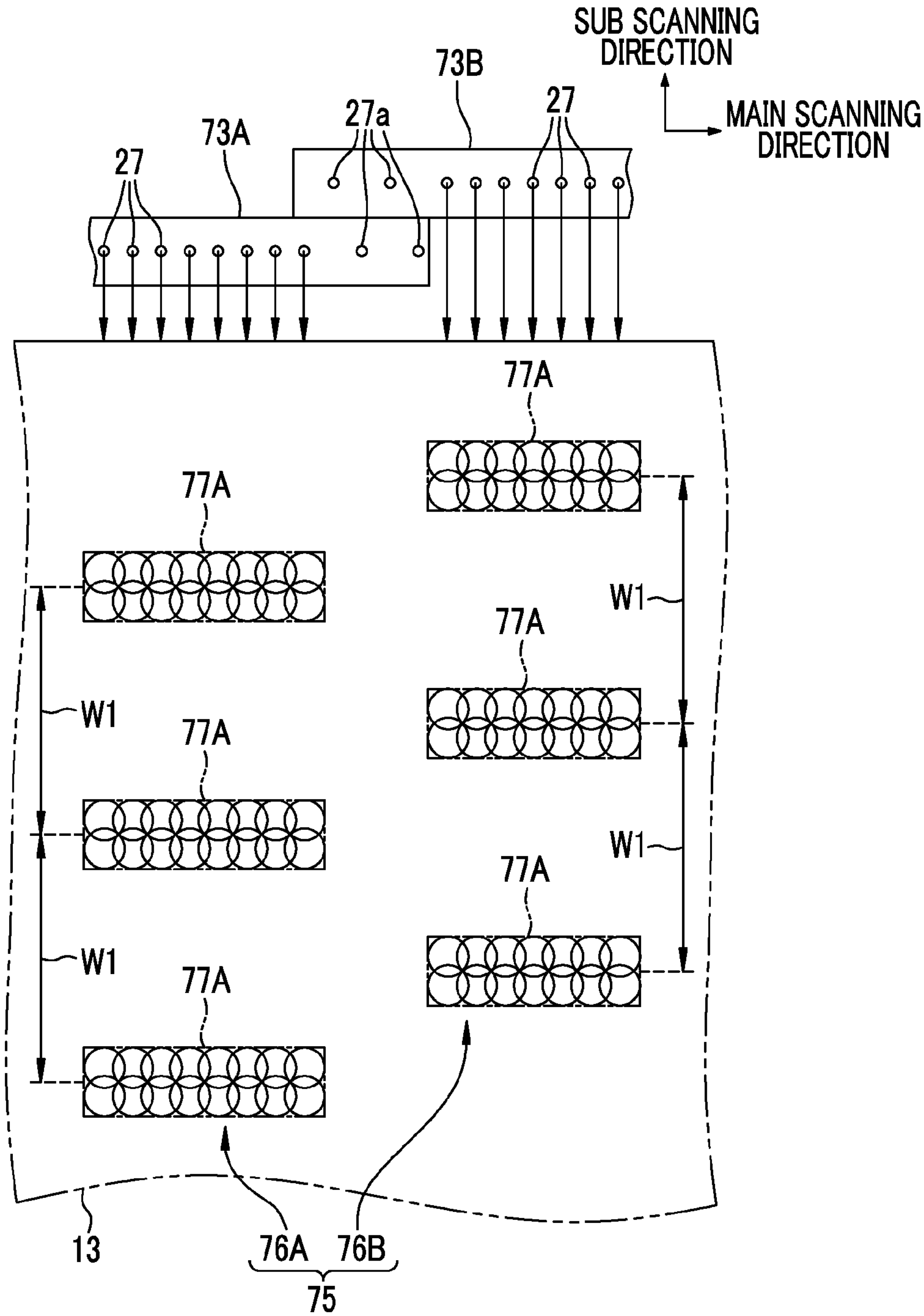

SUB SCANNING DIRECTION
MAIN SCANNING DIRECTION
73B
27a
27
73A
27
77A
77A
W1
77A
W1
77A
W1
77A
W1
77A
13
76A
76B
75

FIG. 20

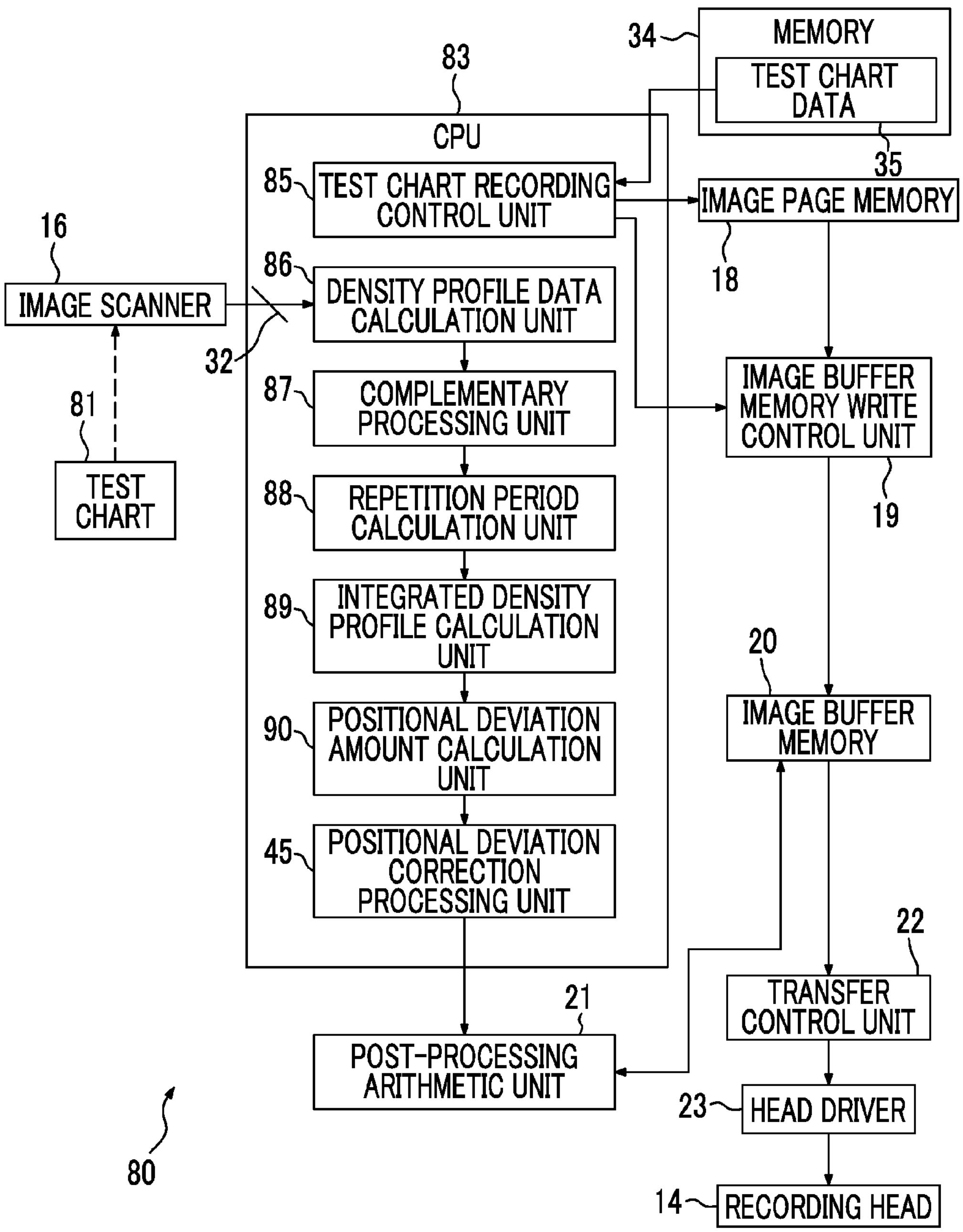

83
CPU
85
TEST CHART RECORDING CONTROL UNIT
86
DENSITY PROFILE DATA CALCULATION UNIT
87
COMPLEMENTARY PROCESSING UNIT
88
REPETITION PERIOD CALCULATION UNIT
89
INTEGRATED DENSITY PROFILE CALCULATION UNIT
90
POSITIONAL DEVIATION AMOUNT CALCULATION UNIT
45
POSITIONAL DEVIATION CORRECTION PROCESSING UNIT
34
MEMORY
TEST CHART DATA
35
IMAGE PAGE MEMORY
18
16
IMAGE SCANNER
32
81
TEST CHART
IMAGE BUFFER MEMORY WRITE CONTROL UNIT
19
20
IMAGE BUFFER MEMORY
22
TRANSFER CONTROL UNIT
21
POST-PROCESSING ARITHMETIC UNIT
23
HEAD DRIVER
14
RECORDING HEAD
80

FIG. 21

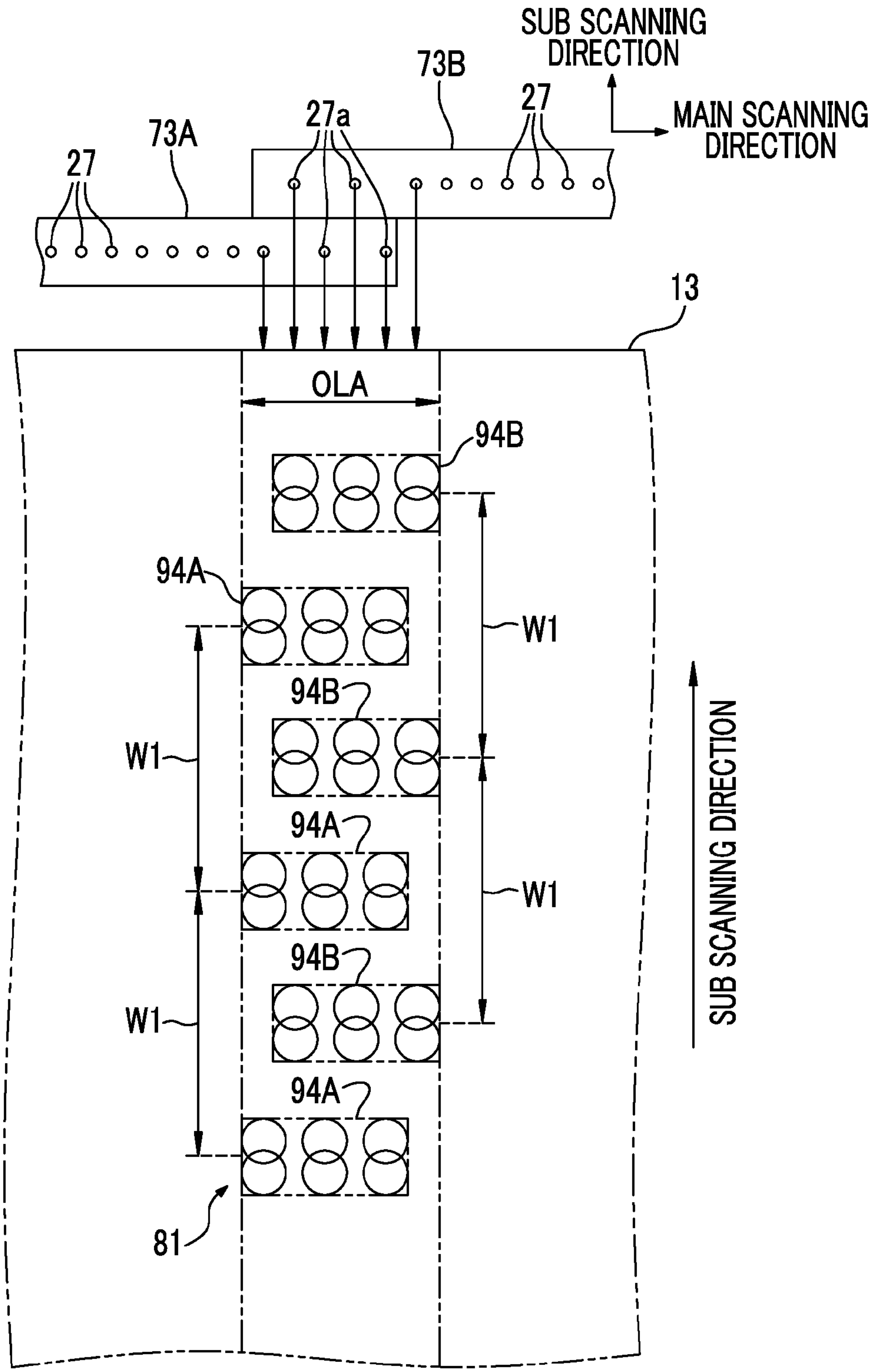

SUB SCANNING DIRECTION
MAIN SCANNING DIRECTION
73B
27a
27
73A
27
13
OLA
94B
94A
W1
94B
W1
94A
W1
94B
W1
94A
81
SUB SCANNING DIRECTION

FIG. 22A

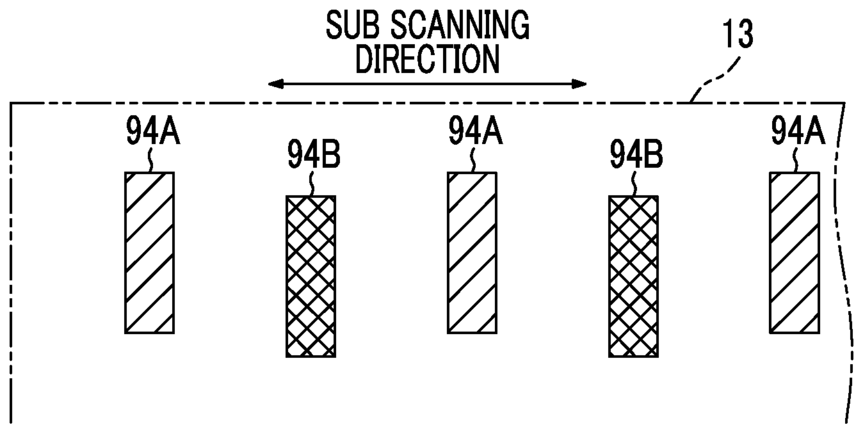


FIG. 22B

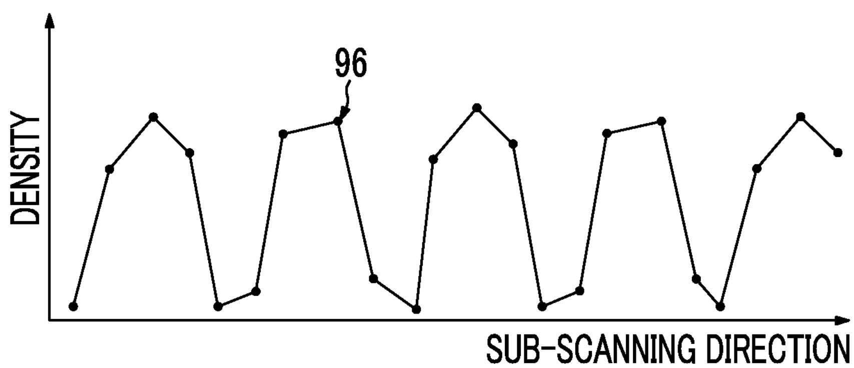


FIG. 22C

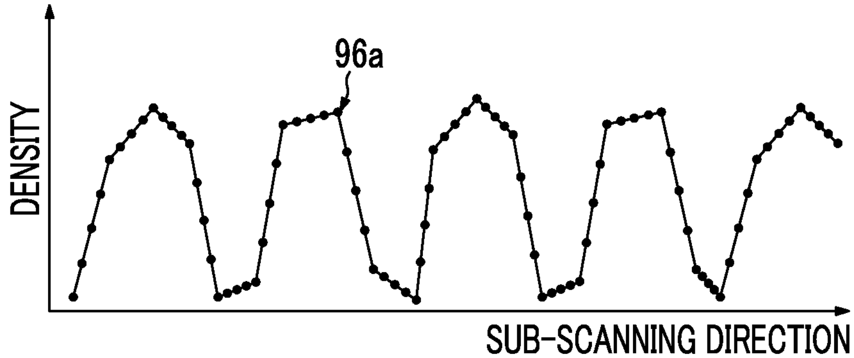


FIG. 23A

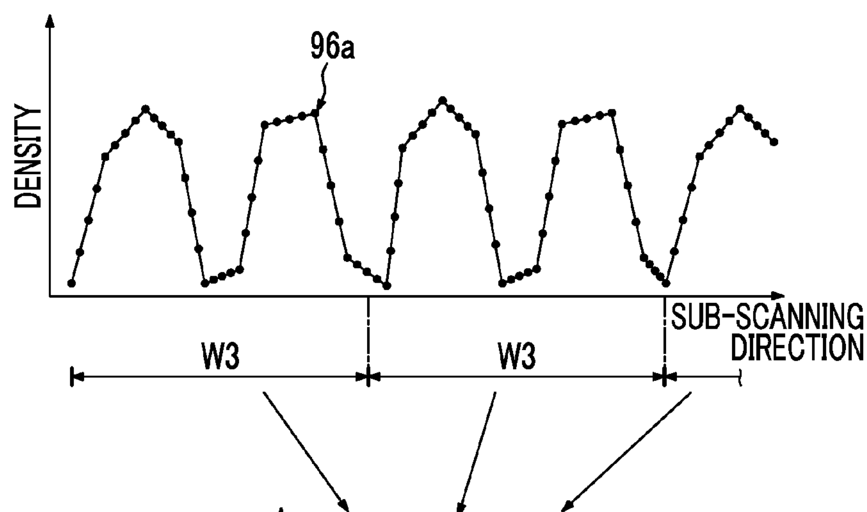


FIG. 23B

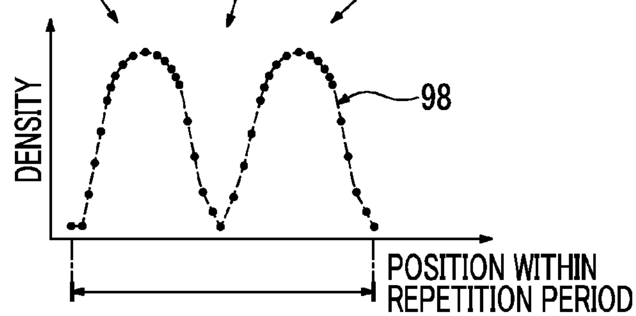


FIG. 23C

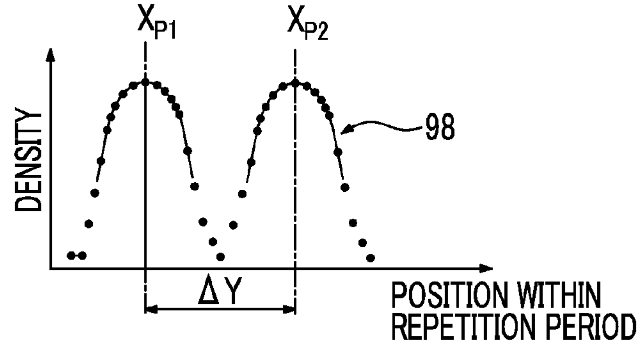


FIG. 24

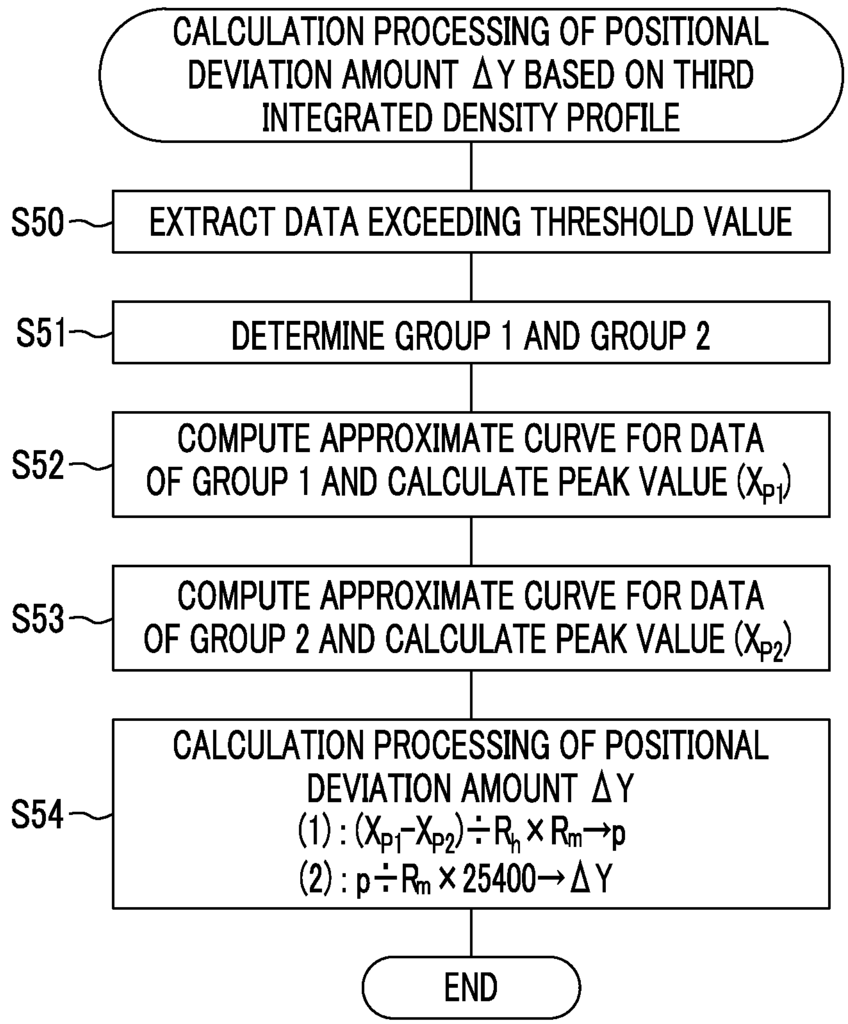

CALCULATION PROCESSING OF POSITIONAL DEVIATION AMOUNT ΔY BASED ON THIRD INTEGRATED DENSITY PROFILE
S50
EXTRACT DATA EXCEEDING THRESHOLD VALUE
S51
DETERMINE GROUP 1 AND GROUP 2
S52
COMPUTE APPROXIMATE CURVE FOR DATA OF GROUP 1 AND CALCULATE PEAK VALUE (X_{P1})
S53
COMPUTE APPROXIMATE CURVE FOR DATA OF GROUP 2 AND CALCULATE PEAK VALUE (X_{P2})
S54
CALCULATION PROCESSING OF POSITIONAL DEVIATION AMOUNT ΔY
(1) : $(X_{P1}-X_{P2}) \div R_h \times R_m \rightarrow p$
(2) : $p \div R_m \times 25400 \rightarrow \Delta Y$
END

FIG. 25

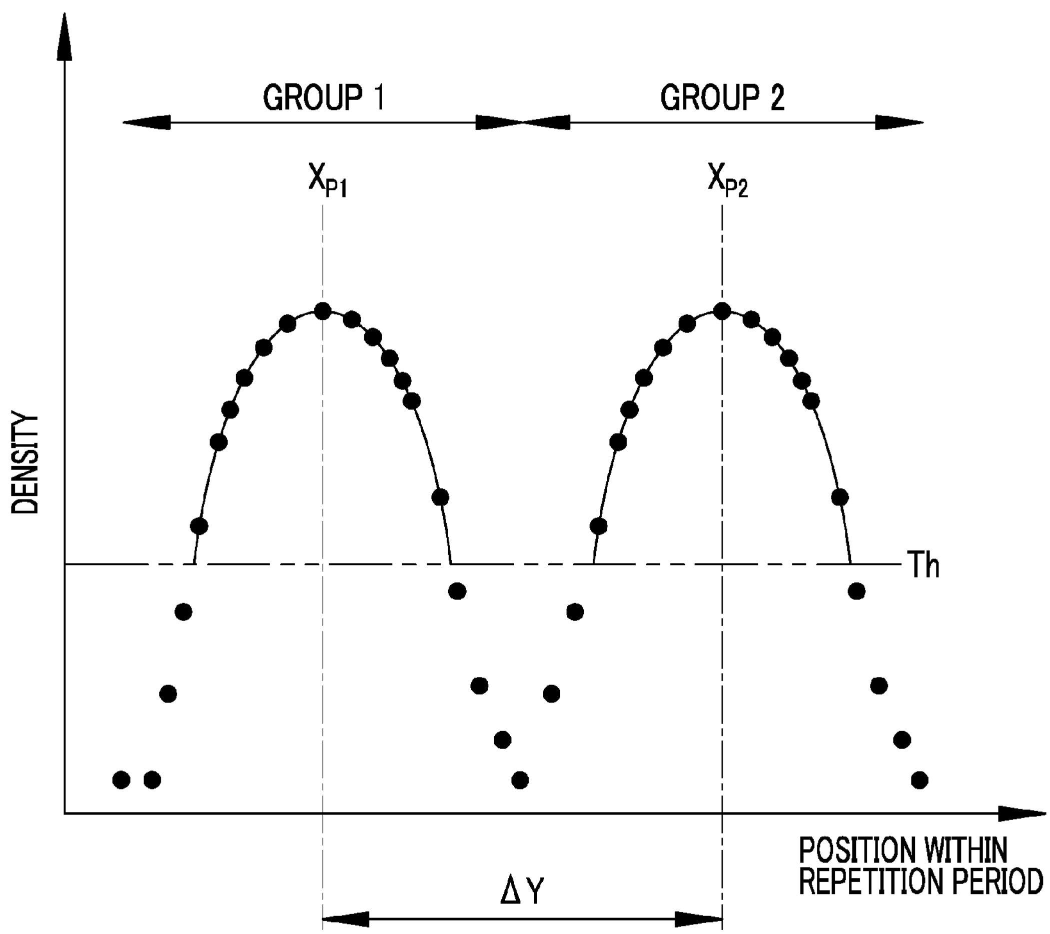

GROUP 1
GROUP 2
X_{P1}
X_{P2}
DENSITY
Th
POSITION WITHIN REPETITION PERIOD
ΔY

FIG. 26

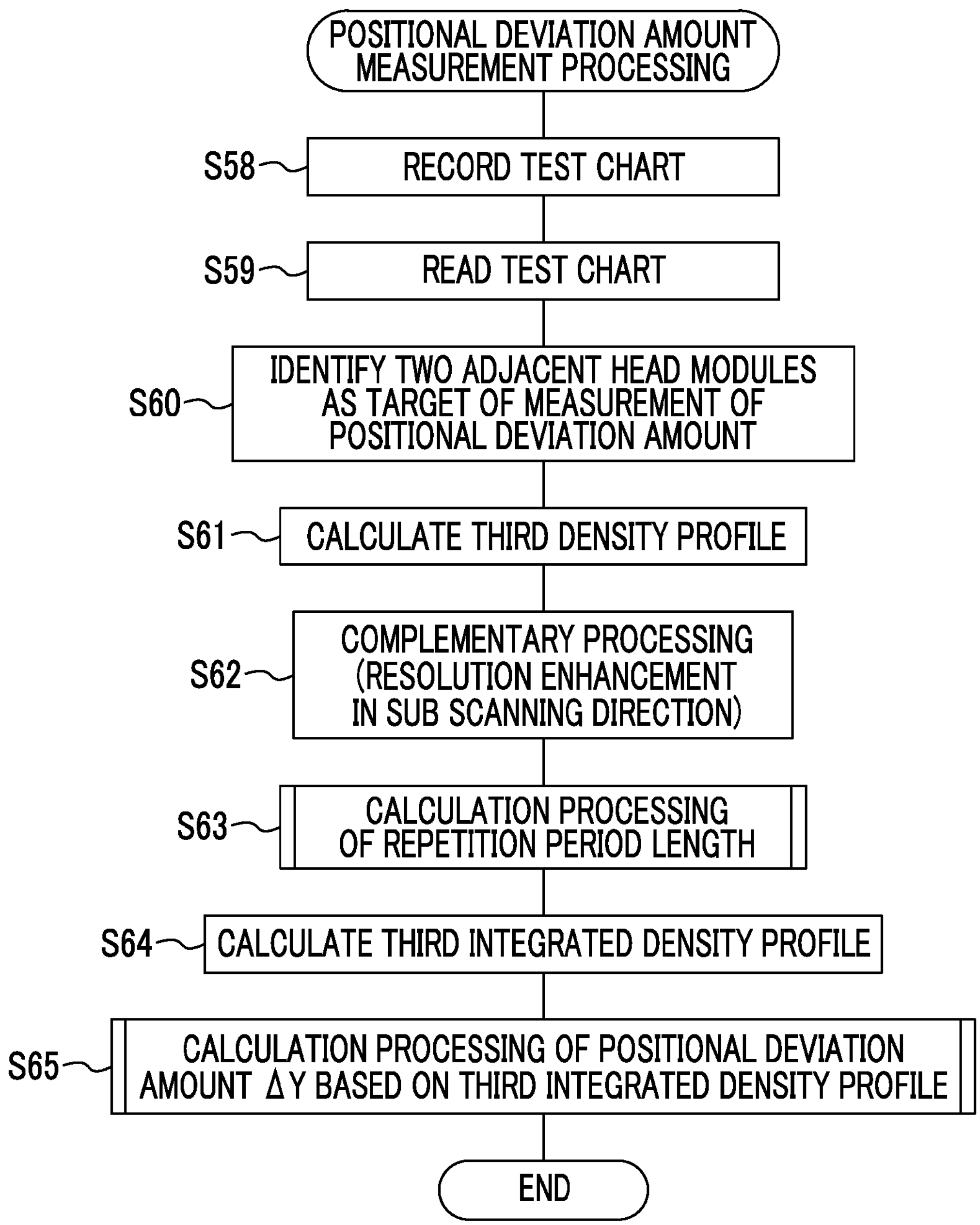

POSITIONAL DEVIATION AMOUNT MEASUREMENT PROCESSING
S58
RECORD TEST CHART
S59
READ TEST CHART
S60
IDENTIFY TWO ADJACENT HEAD MODULES AS TARGET OF MEASUREMENT OF POSITIONAL DEVIATION AMOUNT
S61
CALCULATE THIRD DENSITY PROFILE
S62
COMPLEMENTARY PROCESSING (RESOLUTION ENHANCEMENT IN SUB SCANNING DIRECTION)
S63
CALCULATION PROCESSING OF REPETITION PERIOD LENGTH
S64
CALCULATE THIRD INTEGRATED DENSITY PROFILE
S65
CALCULATION PROCESSING OF POSITIONAL DEVIATION AMOUNT ΔY BASED ON THIRD INTEGRATED DENSITY PROFILE
END

FIG. 27

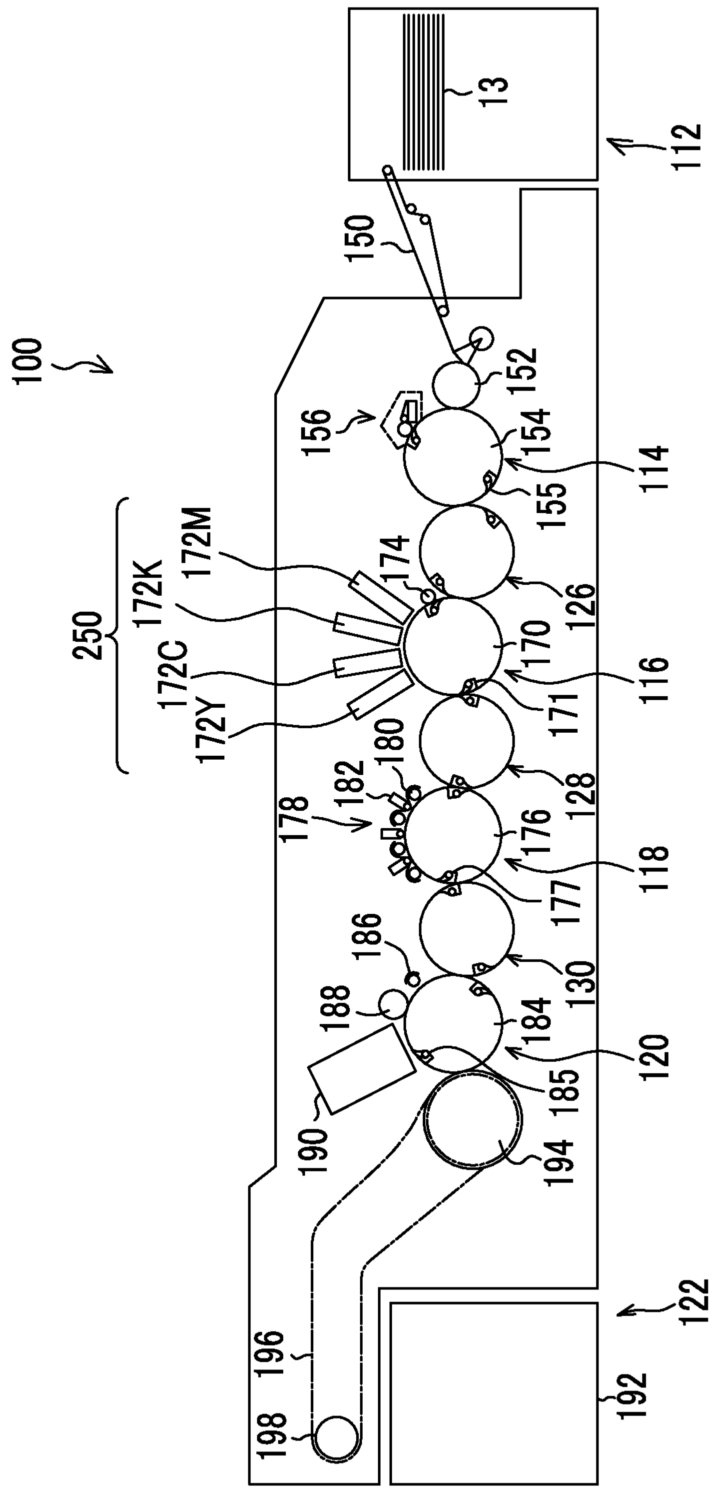

100
13
112
150
152
154
155
156
114
250
172M
172K
172C
172Y
174
126
170
171
116
178
182
180
128
176
177
118
186
188
130
184
185
120
190
194
122
196
192
198

FIG. 28

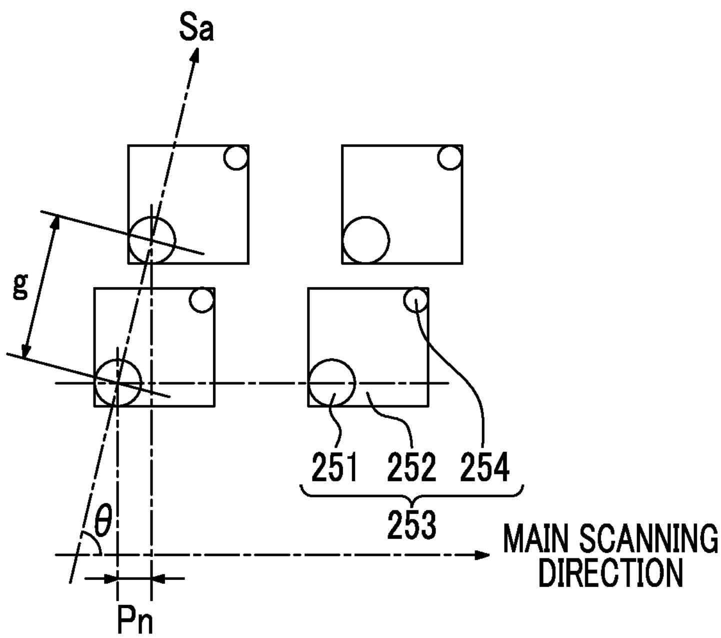
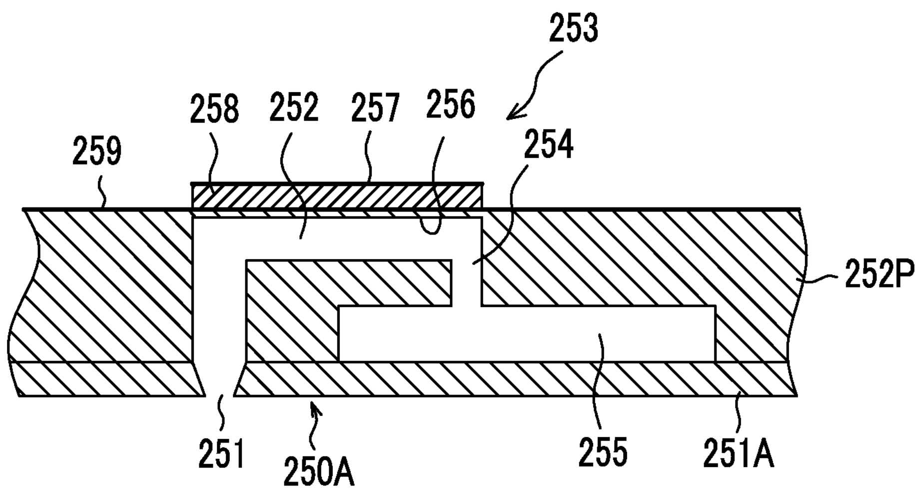


FIG. 29



METHOD FOR MEASURING AMOUNT OF POSITIONAL DEVIATION AND IMAGE-RECORDING DEVICE

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is a Continuation of PCT International Application No. PCT/JP2014/54370, filed on Feb. 24, 2014, which claims priority under 35 U.S.C. §119(a) to Japanese Patent Application No. 2013-053226, filed on Mar. 15, 2013. Each of the above application(s) is hereby expressly incorporated by reference, in its entirety, into the present application.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a method for measuring the amount of positional deviation which measures the amount of positional deviation between recording positions of a plurality of head modules of a recording head, and an image-recording device which measures the amount of positional deviation using the method.

2. Description of the Related Art

As a recording system of an ink jet printer (image-recording device), a line system which records an image with a single drawing pass by a line head along with transport of a recording medium is known. In the line system, a long line head (recording head) is used along a width direction (main scanning direction) of the recording medium orthogonal to a transport direction (sub scanning direction) of the recording medium. It is not realistic to integrally form the line head of silicon wafer, glass, or the like due to problems of yield, heat, cost, and the like. For this reason, in the line system, a line head in which head modules each having nozzles arranged in a two-dimensional manner are arranged in parallel in the width direction of the recording medium is usually used.

When performing image recording using the line head, if the position of the individual head module is deviated in the sub scanning direction, the recording position of the individual head module undergoes a positional deviation in the sub scanning direction; thus, there is a problem in that quality of a recorded image is degraded. For this reason, various methods which detect the amount of positional deviation in the sub scanning direction of the recording position of each head module are suggested.

In a method for measuring the amount of positional deviation described in JP 4770256B, first, line patterns extended long in the width direction of the recording medium are recorded at intervals of n pixels in the sub scanning direction centering on a reference line by one of adjacent head module to form a first line group. Simultaneously, line patterns are recorded at intervals of n+1 pixels in the sub scanning direction centering on the reference line by the other head module to form a second line group. Next, the first line group is compared to the second line group to identify a first line pattern of the first line group and a second line pattern of the second line group aligned in the transport direction. The amount of positional deviation is calculated as $[k\times((n+1)-n)]$ pixels based on the amount of positional deviation (a k-th position from the reference pattern) from the first and second line patterns. With this, it is possible to measure the amount of positional deviation in the sub scanning direction between the recording positions of adjacent head modules in terms of pixels.

SUMMARY OF THE INVENTION

If the method for measuring the amount of positional deviation of JP 4770256B is used, it is possible to measure the amount of positional deviation of the recording position between the head modules in terms of pixels; thus, it is possible to perform the correction of the amount of positional deviation in terms of pixels. However, the inventors have found experimentally that, if the amount of positional deviation of the recording position between the head modules does not fall within about ±5μ, image quality of a recorded image is degraded. For this reason, for example, when recording resolution is 1200 dpi, it is necessary to measure the amount of positional deviation of the recording position between the head modules with accuracy of about 1/4 pixels.

When measuring the amount of positional deviation, a read image obtained by reading a test chart or the like recorded by each head module with an image sensor of an image scanner is analyzed; however, in order to measure the amount of positional deviation on the order of about 1/4 pixels, a high-resolution image sensor is required. As a result, manufacturing cost of a device which measures the amount of positional deviation is increased.

An aspect of the invention is to provide a method for measuring the amount of positional deviation capable of measuring the amount of positional deviation of a recording positions between head modules with high accuracy, and an image-recording device which measures the amount of positional deviation using the method.

A method for measuring the amount of positional deviation for attaining the object of the invention includes a recording step of, while relatively moving a recording head with a plurality of head modules each having a plurality of recording elements arranged in a first direction and a recording medium in a second direction orthogonal to the first direction, recording dot patterns having a shape extended in the first direction on the recording medium at intervals determined in advance in the second direction using a first head module and a second head module among the plurality of head modules, a reading step of optically reading the dot patterns recorded on the recording medium in the recording step, a density profile calculation step of calculating a density profile representing change in density in the second direction of a read image of the dot patterns read in the reading step, a repetition period calculation step of calculating a repetition period of a waveform corresponding to each dot pattern in the density profile based on a calculation result in the density profile calculation step, an integrated density profile calculation step of integrating data of the density profile based on a calculation result of the repetition period calculation step in each repetition period to calculate an integrated density profile, and a positional deviation amount calculation step of obtaining a peak position of a waveform corresponding to each dot pattern in the integrated density profile based on a calculation result of the integrated density profile calculation step and calculating the amount of positional deviation in the second direction between a recording position of the first head module and a recording position of the second head module based on each peak position.

According to the invention, since the amount of positional deviation in the second direction of the recording position between the head modules is calculated based on the read image of the dot patterns recorded on the recording medium at intervals determined in advance in the second direction for each head module, it is possible to measure the amount of positional deviation in the second direction of the recording position between the head modules with high accuracy without using a high-resolution image sensor.

It is preferable that, in the density profile calculation step, a first density profile corresponding to a first dot pattern recorded by the first head module and a second density profile corresponding to a second dot pattern recorded by the second head module are calculated as the density profile, in the repetition period calculation step, a first repetition period of a waveform corresponding to the first dot pattern and a second repetition period representing a repetition period of a waveform corresponding to the second dot pattern are calculated as the repetition period based on the first and second density profiles, in the integrated density profile calculation step, a first integrated density profile obtained by integrating data of the first density profile in each first repetition period and second integrated density profile obtained by integrating data of the second density profile in each second repetition period are calculated as the integrated density profile, and in the positional deviation amount calculation step, a first peak position of a waveform corresponding to the first dot pattern in the first integrated density profile and a second peak position of a waveform corresponding to the second dot pattern in the second integrated density profile are obtained, and the amount of positional deviation is calculated based on the difference between the first peak position and the second peak position. With this, it is possible to measure the amount of positional deviation in the second direction of the recording position between the head modules with high accuracy.

It is preferable that the first head module and the second head module are adjacent to each other in the first direction. With this, it is unlikely to be affected by the tilt (rotation displacement of the recording head with a direction perpendicular to the surface of the recording medium) of the recording head, an error of the transport speed of the recording medium, deformation of the recording medium, an error of reading of the read image of the dot patterns, or the like, it is possible to measure the amount of positional deviation with higher accuracy.

It is preferable that, in an overlap recording area where recording areas on the recording medium of the first and second head modules partially overlap each other, in the recording step, the first dot pattern and the second dot pattern are recorded by the recording elements of the first and second head modules which perform recording in a recording area other than the overlap area. With this, even when the recording areas of the head modules adjacent to each other in the first direction overlap each other, it is possible to measure the amount of positional deviation in the second direction of the recording position between the head modules with high accuracy.

It is preferable that, in an overlap recording area where recording areas on the recording medium of the first and second head modules partially overlap each other, in the recording step, a first dot pattern and a second dot pattern are individually recorded alternately at intervals determined in advance in the second direction as the dot patterns using the recording elements of the first and second head modules which perform recording in the overlap recording area, in the density profile calculation step, a third density profile corresponding to the first dot pattern and the second dot pattern is calculated as the density profile, in the repetition period calculation step, a third repetition period representing a repetition period of a waveform corresponding to the first and second dot patterns in the third density profile is calculated, in the integrated density profile calculation step, a third integrated density profile obtained by integrating data of the third density profile in each third repetition period is calculated as the integrated density profile, and in the positional deviation amount calculation step, a first peak position of a waveform corresponding to the first dot pattern and a second peak position of a waveform corresponding to the second dot pattern in the third integrated density profile are obtained, and the amount of positional deviation is calculated based on the difference between the first peak position and the second peak position. With this, even when the recording areas of the head modules adjacent each other in the first direction overlap each other, it is possible to measure the amount of positional deviation in the second direction of the recording position between the head modules with high accuracy. Furthermore, it is possible to reduce the time necessary for calculating the amount of positional deviation.

The repetition period calculation step has a temporary integrated density profile calculation step of integrating data of the density profile in each temporary repetition period to calculate a temporary integrated density profile, a repetition step of, while changing the temporary repetition period, repeatedly executing the temporary integrated density profile calculation step to calculate the temporary integrated density profile in each temporary repetition period, and a determination step of comparing a maximum value of the temporary integrated density profile in each temporary repetition period and determining the temporary repetition period with the greatest maximum value as the repetition period. With this, it is possible to more accurately calculate the repetition period.

It is preferable that the method further includes a complementary processing step of performing complementary processing on a density profile calculated in the density profile calculation step to enhance the resolution of the density profile in the second direction, and in the repetition period calculation step, a repetition period is calculated based on a density profile subjected to the complementary processing. With this, it is possible to calculate the amount of positional deviation with higher accuracy.

It is preferable that the first direction is a width direction of the recording medium.

It is preferable that the recording head is an ink jet head.

An image-recording device for attaining the object of the invention includes a recording head with a plurality of head modules each having a plurality of recording elements arranged in a first direction, a relative moving unit which relatively moves the recording head and a recording medium in a second direction orthogonal to the first direction, a recording control unit which controls the recording head and the relative moving unit such that dot patterns having a shape extended in the first direction are recorded on the recording medium at intervals determined in advance in the second direction using a first head module and a second head module among the plurality of head modules, a reading unit which optically reads the dot patterns recorded on the recording medium using the first head module and the second head module, a density profile calculation unit which calculates a density profile representing change in density in the second direction of a read image of the dot patterns read by the reading unit, a repetition period calculation unit which calculates a repetition period corresponding to each dot pattern in the density profile based on a calculation result of the density profile calculation unit, an integrated density profile calculation unit which integrates data of the density profile based on a calculation result of the repetition period calculation unit in each repetition period to calculate an integrated density profile, and a positional deviation amount calculation unit which obtains a peak position of a waveform corresponding to each dot pattern in the integrated density profile based on a calculation result of the integrated density profile calculation unit and calculates the amount of positional deviation in the second direction between a recording position of the first head module and a recording position of the second head module based on the peak position.

The method for measuring the amount of positional deviation and the image-recording device of the invention can measure the amount of positional deviation of the recording position between the head modules with high accuracy.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a schematic view of an ink jet printer of a first embodiment.

FIG. **2** is a top view of a recording head of the first embodiment.

FIG. **3** is an explanatory view illustrating a positional deviation of a recording position of the first embodiment.

FIG. **4** is a functional block diagram of a CPU of the first embodiment.

FIG. **5** is a schematic view of a test chart of the first embodiment.

FIGS. **6**A and **6**B are explanatory views illustrating calculation of a first density profile, and FIG. **6**C is an explanatory view illustrating complementary processing.

FIG. **7**A is an explanatory view illustrating calculation of a repetition period length, FIG. **7**B is an explanatory view illustrating calculation of a first integrated density profile, and FIG. **7**C is an explanatory view illustrating calculation of a reference amount of positional deviation Δy**1**.

FIG. **8** is a flowchart showing the flow of calculation processing of a repetition period length.

FIG. **9** is an explanatory view illustrating processing of Step S9 in FIG. **8**.

FIG. **10** is a flowchart showing the flow of calculation processing of a reference amount of positional deviation.

FIG. **11** is an explanatory view illustrating a reference amount of positional deviation Δy**1**.

FIG. **12** is an explanatory view illustrating calculation processing of a reference amount of positional deviation Δy**2**.

FIG. **13** is an explanatory view illustrating calculation processing of an amount of positional deviation ΔY of the first embodiment.

FIG. **14** is a flowchart showing the flow of image recording processing of a printer of the first embodiment.

FIG. **15** is a flowchart showing the flow of positional deviation amount measurement processing of the first embodiment.

FIG. **16** is a flowchart showing the flow of reference positional deviation amount measurement processing.

FIG. **17** is a top view of a recording head of an ink jet printer of a second embodiment.

FIG. **18** is an explanatory view illustrating positional deviation of a recording position of the second embodiment.

FIG. **19** is a schematic view of a test chart of the second embodiment.

FIG. **20** is a functional block diagram of a CPU of an ink jet printer of the third embodiment.

FIG. **21** is a schematic view of a test chart of the third embodiment.

FIGS. **22**A and **22**B are explanatory views illustrating calculation of a third density profile, and FIG. **22**C is an explanatory view illustrating complementary processing.

FIG. **23**A is an explanatory view illustrating calculation of a repetition period length, FIG. **23**B is an explanatory view illustrating calculation of a third integrated density profile, and FIG. **23**C is an explanatory view illustrating calculation of an amount of positional deviation ΔY.

FIG. **24** is a flowchart showing the flow of calculation processing of the amount of positional deviation ΔY.

FIG. **25** is an explanatory view specifically illustrating calculation of the amount of positional deviation ΔY.

FIG. **26** is a flowchart showing the flow of positional deviation amount measurement processing of the third embodiment.

FIG. **27** is a schematic view of an ink jet printer of another example.

FIG. **28** is a schematic view showing a structure example of an ink jet head.

FIG. **29** is a schematic view of an ink jet head.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Ink Jet Printer of First Embodiment

<Configuration of Ink Jet Printer>

As shown in FIG. **1**, an ink jet printer (hereinafter, simply referred to as a printer) **10** corresponding to an image-recording device of the invention is connected to an external host computer **11**. The printer **10** deposits ink droplets on a recording sheet (recording medium, see FIG. **2**) **13** transported by a transport mechanism (relative moving unit) **12** from a recording head **14** based on image data input from the host computer **11** to record an image on the recording sheet **13**. In FIG. **1**, only a portion relating to processing of image data is primarily shown.

The printer **10** includes, in addition to the transport mechanism **12** and the recording head **14** described above, an image scanner (reading unit) **16**, a host interface (I/F) unit **17**, an image page memory **18**, an image buffer memory write control unit **19**, an image buffer memory **20**, a post-processing arithmetic unit **21**, a transfer control unit **22**, a head driver **23**, a CPU **24**, and the like. The host I/F unit **17**, the image page memory **18**, the image buffer memory write control unit **19**, and the CPU **24** are connected through a bus **25**.

As shown in FIG. **2**, the transport mechanism **12** relatively moves the recording sheet **13** in a sub scanning direction (second direction) perpendicular to the width direction of the recording sheet **13** with respect to the recording head **14** to pass through below the recording head **14**. The recording head **14** ejects ink from nozzles **27** arranged on the lower surface (nozzle surface) thereof and forms an image on the recording sheet **13** during relative movement. FIG. **2** is a top view of the recording head **14**, and shows the nozzles **27** arranged on the lower surface of the recording head **14** in perspective view. In order to prevent complication of the drawing, the arrangement of the nozzles **27** is simplified.

The recording head **14** is a line head which extends long in a main scanning direction (first direction) parallel to the width direction of the recording sheet **13**, and has a length corresponding to the width of the recording sheet **13**. The recording head **14** is provided for each color (CMYK) to be recorded.

The recording head **14** includes three replaceable head modules of a first head module **28**A, a second head module **28**B, and a third head module **28**C, and a frame body **29** which retains the head modules **28**A to **28**C. The head modules **28**A to **28**C are arranged in zigzag in the main scanning direction. The end portions of two adjacent head modules among the head modules **28**A to **28**C overlap each other. The recording head **14** may also include tow or, or four or more replaceable head modules of a first head module **73**A.

The nozzles **27** of each of the head modules **28**A to **28**C are arranged so as to be handled equivalent to those linearly arranged at a substantially equal pitch in the main scanning direction. Accordingly, an ink droplet adjacent to an ink droplet deposited using the nozzle **27** at the rightmost end of the first head module **28**A in FIG. **2** in the main scanning direction (in this case, the right direction of FIG. **2**) can be deposited using the nozzle **27** at the leftmost end of the second head module **28**B in FIG. **2**. An ink droplet adjacent to an ink droplet deposited using the nozzle **27** at the rightmost end of the second head module **28**B in FIG. **2** in the main scanning direction (in this case, the right direction of FIG. **2**) can be deposited using the nozzle **27** at the leftmost end of the third head module **28**C in FIG. **2**.

The image scanner **16** is arranged at a position on the downstream side of the recording sheet transport direction of the recording head **14** to face the recording surface of the recording sheet **13**. The image scanner **16** is extended long in the main scanning direction and has a length corresponding to the width of the recording sheet **13**. The image scanner **16** optically reads a test chart **31** (see FIG. **5**) recorded on the recording surface of the recording sheet **13** by the recording head **14** and outputs test chart read image data **32** (hereinafter, simply referred to as read image data, see FIG. **1**) corresponding to a read image of the invention to the CPU **24**. As the image scanner **16**, an image scanner whose resolution in the sub scanning direction is, for example, about 100 dpi, is used. That is, in this embodiment, reading of the test chart **31** is performed without using a high-resolution image scanner.

Returning to FIG. **1**, the host I/F unit **17** is a communication interface which receives image data sent from the host computer **11**, and various serial interfaces or parallel interfaces can be used. The host I/F unit **17** sends received image data to the image page memory **18**.

The image page memory **18** stores image data input from the host I/F unit **17**, and a DRAM or the like which has storage capacity capable of print data for one page is used.

The image buffer memory write control unit **19** reads print data for one line from the image page memory **18** line by line and transfers print data to the image buffer memory **20**. Print data for one line is transferred to the image buffer memory **20** and is stored in continuous addresses on the image buffer memory **20**. Print data for a plurality of lines is accumulated in the image buffer memory **20**.

The post-processing arithmetic unit **21** performs post-processing (correction processing), such as mask processing (deposition inhibition processing) of an abnormal nozzle or shading correction processing (processing for increasing or decreasing a deposition rate for each nozzle), on the image buffer memory **20**. Data subjected to the post-processing is rewritten to the image buffer memory **20**.

The transfer control unit **22** reads print data for single deposition (for all nozzles of the head modules **28**A to **28**C) from the image buffer memory **20** and transfers print data to the head driver **23**. The transfer control unit **22** performs division processing for dividing print data for single deposition for each of the head modules **28**A to **28**C and transmitting print data to the head driver **23**, or transfer format adjustment.

The head driver **23** is constituted by three drivers (not shown) which individually control driving of head modules **28**A to **28**C. The head driver **23** controls driving actuators (not shown) corresponding to the nozzles **27** of the head modules **28**A to **28**C based on print data for head modules **28**A to **28**C input from the transfer control unit **22**, and ejects ink droplets from the nozzles **27**. An image is formed on the recording surface of the recording sheet **13** by controlling ink ejection from the head modules **28**A to **28**C in synchronization with the transport speed of the recording sheet **13**.

The CPU **24** successively executes various programs or data read from a memory **34** based on an input signal from an operating unit (not shown) to control the respective units of the printer **10**. In a ROM area of the memory **34**, in addition to various programs and the like described above, test chart data **35** (see FIG. **4**) which is image data of the test chart **31** is stored. A RAM area of the memory **34** is used as a development area of a program executed by the CPU **24** and an arithmetic operation area of the CPU **24**.

The CPU **24** calculates the amount of positional deviation ΔY in the sub scanning direction of the recording position between two arbitrary head modules among the head modules **28**A to **28**C by analyzing read image data **32** input from the image scanner **16** (see FIG. **13**). The CPU **24** executes positional deviation correction processing for correcting the recording position between the head modules based on a detection result of the amount of positional deviation ΔY. Hereinafter, "the positional deviation in the sub scanning direction" is simply referred to as "positional deviation".

As shown in FIG. **3**, the positional deviation of the recording position between the head modules occurs due to, for example, the actual positional deviation of the head modules **28**A to **28**C. Though not shown, the positional deviation of the recording position also occurs due to flight deflection of ink droplets **36** ejected from the nozzles **27** of the head modules **28**A to **28**C.

<Configuration Relating to Measurement of Amount of Positional Deviation>

As shown in FIG. **4**, the CPU **24** reads and executes a program relating to measurement of the amount of positional deviation ΔY or positional deviation correction from the memory **34** to function as a test chart recording control unit (recording control unit) **38**, a density profile data calculation unit **39**, a complementary processing unit **40**, a repetition period calculation unit **41**, an integrated density profile calculation unit **42**, a reference positional deviation amount calculation unit **43**, a positional deviation amount calculation unit **44**, and a positional deviation correction processing unit **45**.

The test chart recording control unit **38** executes recording of the test chart **31** at a predetermined timing, such as at the time of power-on of the printer **10**, at the time of replacement of one of the head modules **28**A to **28**C, at the time of a measurement operation of the amount of positional deviation ΔY, at the time of recording of a predetermined number of sheets, or at the time of elapse of a predetermined time.

The test chart recording control unit **38** outputs test chart data **35** read from the memory **34** to the image page memory **18** and operates the image buffer memory write control unit **19**, the transfer control unit **22**, and the head driver **23** at the predetermined timing described above. With this, print data for single deposition based on test chart data **35** is successively transferred to the head driver **23** through the image buffer memory write control unit **19**, the image buffer memory **20**, the post-processing arithmetic unit **21**, and the transfer control unit **22**. The head driver **23** controls ink ejection of the nozzles **27** of the head modules **28**A to **28**C based on print data. The ink droplets **36** are deposited by the head modules **28**A to **28**C while transporting the recording sheet **13** by the transport mechanism **12**, whereby the test chart **31** is recorded on the recording surface of the recording sheet **13**. At this time, it is desirable to set the ink ejection timing of each of the head modules **28**A to **28**C to a value determined in advance and to record the test chart **31** such that the test chart **31** recorded on the recording surface substantially has the same shape as test chart data **35**.

As shown in FIG. **5**, the test chart **31** includes a first dot pattern group **48**A, a second dot pattern group **48**B, and a third dot pattern group (not shown) recorded by the head modules **28**A to **28**C. The first dot pattern group **48**A has, for example, 150 first dot pattern **50**A having a shape extended long in the main scanning direction (for example, 5 pixl×64 pixl) at pattern intervals W1 (repetition period) determined in advance in the sub scanning direction. The term "pattern interval W1" used herein is an interval between the positions of the centers of gravity of adjacent dot patterns in the sub scanning direction, the interval between the center positions, or the interval between specific dots.

The second dot pattern group **48**B has, for example, 150 second dot patterns **50**B having the same shape as the first dot pattern **50**A at the pattern intervals W1 (repetition period) in the sub scanning direction. Each second dot pattern **50**B is recorded to be deviated from each first dot pattern **50**A by an amount according to the positional deviation between the first and second head modules **28**A and **28**B in the sub scanning direction.

Similarly to the first and second dot pattern groups **48**A and **48**B, the third dot pattern group has, for example, 150 third dot patterns (not shown) having the same shape as the first dot pattern **50**A at the pattern intervals W1 in the sub scanning direction.

The test chart **31** is read by the image scanner **16**. With this, read image data **32** is output from the image scanner **16** to the density profile data calculation unit **39**.

Returning to FIG. **4**, the respective units **39** to **44** from the density profile data calculation unit **39** to the positional deviation amount calculation unit **44** calculate the amount of positional deviation ΔY of the recording position between two adjacent head modules among the head modules **28**A to **28**C based on read image data **32**. Hereinafter, a case of measuring the amount of positional deviation ΔY of the recording position between the first and second head modules **28**A and **28**B will be described. The first and second head modules **28**A and **28**B correspond to a first head module and a second head module of the invention, and the first and second dot patterns **50**A and **50**B correspond to a first dot pattern and a second dot pattern of the invention.

The amount of positional deviation ΔY is calculated by calculating the amount of deviation (hereinafter, referred to as reference amount of positional deviation) of the recording position of each of the first and second head modules **28**A and **28**B from a reference position determined in advance, and comparing the two reference amounts of positional deviation. The calculation of the reference amounts of positional deviation is executed by the respective units **39** to **43** from the density profile data calculation unit **39** to the reference positional deviation amount calculation unit **43**. Hereinafter, the calculation of the reference amount of positional deviation of the recording position of the first head module **28**A will be described.

<Calculation of Reference Amount of Positional Deviation of Recording Position of First Head Module>

(Calculation of Density Profile)

As shown in FIGS. **6**A and **6**B, the density profile data calculation unit **39** analyzes read image data **32** to calculate a first density profile **53**A representing change in density in the sub scanning direction of an image area with the first dot pattern group **48**A recorded. The first density profile **53**A represents, based on a reference position X_0 determined in advance, change in density of the image area in the sub scanning direction from the reference position X_0. In the first density profile **53**A, the density at a position corresponding to each first dot pattern **50**A becomes higher, and conversely, the density at a position corresponding to between the first dot patterns **50**A becomes lower.

The reference position X_0 is, for example, a position separated from the first dot pattern **50**A positioned in one end portion of the first dot pattern group **48**A in the sub scanning direction by a maximum of (W1)/2 in a direction parallel to the sub scanning direction and away from the first dot pattern group **48**A. The reference position X_0 may be appropriately changed, and may be, for example, between the first dot patterns **50**A.

In this embodiment, since the resolution (for example, 100 dpi) of the image scanner **16** in the sub scanning direction is lower than the resolution (for example, 600 dpi) of the test chart **31** in the sub scanning direction, the resolution of the first density profile **53**A in the sub scanning direction becomes low. That is, the interval of the respective measurement points in the sub scanning direction of the first density profile **53**A is increased. The density profile data calculation unit **39** outputs the first density profile **53**A to the complementary processing unit **40**.

(Complementary Processing: Resolution Enhancement)

As shown in FIG. **6**C, the complementary processing unit **40** performs complementary processing (linear complementary processing) for complementing (also called interpolation) linear complementary data between the measurement values at the respective measurement points of the first density profile **53**A to enhance the resolution of the first density profile **53**A in the sub scanning direction from 100 dpi to 10000 dpi. For example, when the resolution of the image sensor of the image scanner **16** is "R_m", the resolution after resolution enhancement is "R_h", the measurement value (density value) at an arbitrary measurement point i is "D_i", and the measurement value at an adjacent measurement point i+1 is "D_{i+1}", linear complementary data "$D_{i(j)}$" is expressed by Expression (1) described below. However, j is an integer of 1 to $((R_h \div R_m)-1)$. The complementary processing unit **40** outputs a resolution-enhanced first density profile **53**A**1** to the repetition period calculation unit **41**.

$$D_{i(j)}=(((R_h \div R_m)-1)\times D_i+j\times D_{i+1})\div(R_h \div R_m) \quad (1)$$

(Calculation of Repetition Period Length)

As shown in FIG. **7**A, the repetition period calculation unit **41** calculates a repetition period length W2 representing a repetition period (that is, a period in which the peak of the density value appears) of change in density corresponding to the first dot pattern **50**A based on the first density profile **53**A**1**. The repetition period length W2 does not completely match the pattern interval W1 described above, and an error of about several % occurs between the repetition period length W2 and the pattern interval W1 due to a resolution fluctuation factor, such as an error of the transport speed of the recording sheet **13**, deformation of the recording sheet **13**, an error of reading of the image scanner **16**, or the like. If the repetition period length W2 is not accurately obtained, the peak value corresponding to each first dot pattern **50**A is averaged at the time of integration average by the integrated density profile calculation unit **42** described below; thus, accurate integration cannot be performed and the accurate position (see FIG. **11**) of the peak cannot be obtained. Accordingly, the repetition period calculation unit **41** calculates the repetition period length W2 accurately by the following method.

As shown in FIG. **8**, initially, the repetition period calculation unit **41** determines an approximate period (for example, a repetition period when the above-described resolution fluctuation factor, such as the above-described pattern interval W1, is neglected) of a repetition period as a reference period (resolution-enhanced value) of a temporary repetition period (Step S1). Next, the repetition period calculation unit **41** determines a value of several % to 10% of the reference period as a fluctuation range of the temporary repetition period (Step S2). That is, the temporary repetition period is changed in a stepwise manner between (reference period−fluctuation range) to (reference period+fluctuation range).

The repetition period calculation unit **41** sets an initial temporary repetition period to "reference period−fluctuation range" (Step S3). After the setting, the repetition period calculation unit **41** integrates and averages the density value of the first density profile **53A1** in each temporary repetition period to calculate a temporary integrated density profile (Step S4, temporary integrated density profile calculation step). The temporary integrated density profile is basically the same as a first integrated density profile **56**A described below (FIG. **7**B). The repetition period calculation unit **41** obtains the maximum value (maximum amplitude, intensity) of the temporary integrated density profile (Step S5).

Next, the repetition period calculation unit **41** determines a period obtained by increasing the initial temporary repetition period by several % of the above-described fluctuation range as a new temporary repetition period (NO in Step S6, Step S7). The repetition period calculation unit **41** repeatedly executes the calculation of the temporary integrated density profile and the calculation of the maximum value of the temporary integrated density profile based on the new temporary repetition period (Steps S4 and S5). Hereinafter, similarly, the repetition period calculation unit **41** repeatedly executes the processing of Steps S7, S4, and S5 until the maximum value of the temporary integrated density profile corresponding to a final temporary repetition period (reference period+fluctuation range) is calculated (No in Step S6, repetition step).

As shown in FIG. **9**, the repetition period calculation unit **41** calculates the maximum values of the temporary integrated density profiles corresponding to all temporary repetition periods (YES in Step S6), and compares the maximum value of the temporary integrated density profile in each temporary repetition period (Step S8). When the period length of the temporary repetition period is different from the repetition period length W2, the peak position (see FIG. 7A) of the waveform in each temporary repetition period is deviated; thus, if integration average is performed, the peak is averaged and the maximum value of the temporary integrated density profile becomes small. Accordingly, the repetition period calculation unit **41** determines the temporary repetition period with the greatest maximum value as the repetition period length W2 (Step S9, determination step). With this, it is possible to accurately calculate the repetition period length W2. The repetition period calculation unit **41** outputs the calculation result of the repetition period length W2 to the integrated density profile calculation unit **42** along with the above-described first density profile **53A1**.

(Calculation of Integrated Density Profile)

As shown in FIGS. **7**A and **7**B, the integrated density profile calculation unit **42** integrates and averages the density value of the first density profile **53A1** in each repetition period length W2 to calculate the first integrated density profile **56**A. The integrated density profile calculation unit **42** outputs the first integrated density profile **56**A to the reference positional deviation amount calculation unit **43**.

(Calculation of Reference Amount of Positional Deviation)

As shown in FIG. **7**C, the reference positional deviation amount calculation unit **43** analyzes the first integrated density profile **56**A to calculate a reference amount of positional deviation Δy**1** of the recording position of the first head module **28**A. Hereinafter, a calculation method of the reference amount of positional deviation Δy1 will be specifically described.

As shown in FIGS. **10** and **11**, the reference positional deviation amount calculation unit **43** determines a threshold value Th of data of the first integrated density profile **56**A using, for example, Expression (2) described below. The reference positional deviation amount calculation unit **43** extracts data exceeding the threshold value Th among data of the first integrated density profile **56**A (Step S**12**).

$$\text{threshold value } Th = (\text{maximum value} - \text{minimum value}) \times f + \text{minimum value: (where } f \text{ is, for example, 0.5)} \quad (2)$$

Next, the reference positional deviation amount calculation unit **43** computes an approximate curve (for example, quadratic function: $y=ax^2+bx+c$, displayed by a solid line in FIG. **11**) for data exceeding the threshold value Th, and calculates a peak position (also called an apex value) X_P of the approximate curve (Step S**13**). For example, the peak position X_P is calculated based on $X_P=-b\div(2\times a)$.

After the calculation of the peak position X_P, the reference positional deviation amount calculation unit **43** calculates the reference amount of positional deviation Δ**y1** based on the peak position X_P, the reference position X_0 (for example, $X_0=0$), the resolution R_m of the image scanner **16**, and the resolution R_h after resolution enhancement using Expressions (3) and (4) described below (Step S**14**). In Expression (4), "25400" is a conversion factor which converts inches to μm. In the invention, although a position where the waveform of the integrated density profile is maximized is set as a peak position, for example, in the case of an integrated density profile in which data corresponding to a portion with no dot pattern recorded is maximized, a position where the waveform is minimized is set as a peak position (the same applies to other embodiments). The reference positional deviation amount calculation unit **43** outputs the calculation result of the reference amount of positional deviation Δ**y1** to the positional deviation amount calculation unit **44**. With the above, the calculation of the reference amount of positional deviation Δ**y1** of the recording position of the first head module **28**A is completed.

$$(X_P - X_0) \div R_h \times R_m \rightarrow p \text{(pixl/scanner resolution)} \quad (3)$$

$$p \div R_m \times 25400 \rightarrow \Delta y1 \,(\mu m) \quad (4)$$

<Calculation of Reference Amount of Positional Deviation of Recording Position of Second Head Module>

Next, as shown in FIG. **12**, the respective units **39** to **43** from the density profile data calculation unit **39** to the reference positional deviation amount calculation unit **43** calculate a reference amount of positional deviation Δ**y2** of the recording position of the second head module **28**B. Calculation processing of the reference amount of positional deviation Δ**y2** is basically the same as the calculation processing of the reference amount of positional deviation Δ**y1** described above.

The density profile data calculation unit **39** analyzes read image data **32** to calculate a second density profile **53**B representing change in density in the sub scanning direction of an image area with the second dot pattern group **48**B recorded. The second density profile **53**B represents, based on the reference position X_0 determined at the time of the calculation of the first density profile **53**A described above, change in density of the image area in the sub scanning direction from the reference position X_0. That is, the first and second density profiles **53**A and **53**B represent change in density in the sub scanning direction from the common reference position X_0.

The complementary processing unit **40** performs linear complementary processing for the second density profile **53**B to enhance the resolution of the second density profile **53**B in the sub scanning direction from 100 dpi to 10000 dpi. With this, a resolution-enhanced second density profile **53**B **1** is generated.

The repetition period calculation unit **41** calculates the repetition period length W**2** representing the repetition period of change in density corresponding to the second dot pattern **50**B based on the second density profile **53**B**1** using the method shown in FIGS. **8** and **9** described above.

The integrated density profile calculation unit **42** integrates and averages data of the second density profile **53**B **1** in each repetition period length W**2** to calculate a second integrated density profile **56**B.

As shown in FIGS. **10** and **11** described above, the reference positional deviation amount calculation unit **43** calculates a peak position X_P of the second integrated density profile **56**B and calculates the reference amount of positional deviation Δy**2** of the recording position of the second head module **28**B based on the peak position X_P. The reference positional deviation amount calculation unit **43** outputs the calculation result of the reference amount of positional deviation Δy**2** to the positional deviation amount calculation unit **44**.

<Positional Deviation Amount Calculation Processing>

As shown in FIG. **13**, the positional deviation amount calculation unit **44** calculates the amount of positional deviation ΔY based on the difference between the reference amount of positional deviation Δy**1** and the reference amount of positional deviation Δy**2**, that is, the difference between the peak position X_P corresponding to the first dot pattern **50**A and the peak position X_P corresponding to the second dot pattern **50**B. Since the reference amounts of positional deviation Δy**1** and Δy**2** (the peak positions X_P) are calculated based on the common reference position X_0, it is possible to calculate the amount of positional deviation ΔY of the recording position between the first and second head modules **28**A and **28**B by taking the difference between both the reference amounts of positional deviation Δy**1** and Δy**2**. The positional deviation amount calculation unit **44** outputs the calculation result of the amount of positional deviation ΔY to the positional deviation correction processing unit **45**. The amount of positional deviation ΔY is the amount of positional deviation of the recording position including the amount of deviation from a design position shown in FIG. **3**, the amount of deviation due to zigzag arrangement, and an error of the ink ejection timing set in each head module at the time of recording of the test chart.

<Positional Deviation Correction Processing>

Returning to FIG. **4**, the positional deviation correction processing unit **45** performs positional deviation correction processing for correcting the recording position between the first and second head modules **28**A and **28**B based on the detection result of the amount of positional deviation ΔY. For example, the positional deviation correction processing unit **45** controls the post-processing arithmetic unit **21** to perform positional deviation correction processing on print data, thereby advancing or delaying the recording start timing of one of the first and second head modules **28**A and **28**B to the other head module. With this, the positional deviation of the recording position between the first and second head modules **28**A and **28**B is corrected. Various methods are known as a positional deviation correction method which corrects the positional deviation of the recording position between the head modules, and any method may be used.

Operation of Ink Jet Printer of First Embodiment

Next, the operation of the printer **10** having the above-described configuration, in particular, measurement processing of the amount of positional deviation ΔY and image recording processing will be described. Here, a case of measuring the amount of positional deviation ΔY of the recording position between the first and second head modules **28**A and **28**B will be described.

As shown in FIG. **14**, when the printer **10** is powered on, when at least one of the first and second head modules **28**A and **28**B is newly mounted in the recording head **14**, or the like, the respective units **39** to **45** of the CPU **24** are operated to start the measurement processing of the amount of positional deviation ΔY (Step S**20**).

(Test Chart Recording Processing)

As shown in FIG. **15**, test chart data **35** in the memory **34** is output to the image page memory **18**, and then, print data for single deposition based on test chart data **35** is successively transferred to the head driver **23** through the image buffer memory write control unit **19**, the image buffer memory **20**, and the transfer control unit **22** under the control of the test chart recording control unit **38**. The head driver **23** controls ink ejection of the nozzles **27** of the head modules **28**A to **28**C based on print data. Then, the ink droplets **36** are deposited by the head modules **28**A to **28**C while transporting the recording sheet **13** in the sub scanning direction by the transport mechanism **12**, whereby the test chart **31** is recorded on the recording surface of the recording sheet **13** (Step S**21**, recording step).

(Test Chart Reading Processing)

After the recording of the test chart **31**, the CPU **24** tracks the test chart **31** based on known transport speed information of the recording sheet **13**. The CPU **24** starts reading by the image scanner **16** in matching with the timing when the test chart **31** passes through the image scanner **16**. With this, the test chart **31** is read by the image scanner **16**, and read image data **32** is output from the image scanner **16** to the density profile data calculation unit **39** (Step S**22**, reading step).

After the input of read image data **32**, the density profile data calculation unit **39** identifies two head modules as a target of measurement of the amount of positional deviation ΔY, that is, the first and second head modules **28**A and **28**B (Step S**23**). Next, the calculation processing of the reference amount of positional deviation Δy**1** of the recording position of the first head module **28**A is started (Step S**24**).

(Calculation Processing of Reference Amount of Positional Deviation Δy**1**)

As shown in FIG. **16**, the density profile data calculation unit **39** analyzes read image data **32** to calculate the first density profile **53**A shown in FIG. **6**B (Step S**26**, density profile calculation step). The first density profile **53**A is output from the density profile data calculation unit **39** to the complementary processing unit **40**.

The complementary processing unit **40** performs the linear complementary processing for the first density profile **53**A to generate the resolution-enhanced first density profile **53**A**1**, as shown in FIG. **6**C (Step S**27**, complementary processing step). The resolution of the first density profile **53**A is enhanced in the sub scanning direction, whereby it is possible to calculate the reference amount of positional deviation Δy**1** (that is, the amount of positional deviation ΔY) with higher accuracy. The first density profile **53**A**1** is output from the complementary processing unit **40** to the repetition period calculation unit **41**.

The repetition period calculation unit **41** executes the processing of Step S**1** to Step S**9** shown in FIG. **8**, whereby the repetition period length W**2** representing the repetition period of change in density corresponding to the first dot pattern **50**A is calculated, as shown in FIG. **7**A (Step S**28**, repetition period calculation step). The repetition period length W**2** is accurately calculated, whereby it is possible to accurately calculate the peak position X_P of the first integrated density profile **56**A. The calculation result of the repetition period length W**2** is output from the repetition period calculation unit **41** to the integrated density profile calculation unit **42** along with the first density profile **53**A**1**.

As shown in FIG. **7**B, the integrated density profile calculation unit **42** integrates and averages data of the first density profile **53**A**1** in each repetition period length W**2** to calculate the first integrated density profile **56**A (Step S**29**, integrated density profile calculation step). The first integrated density profile **56**A is output from the integrated density profile calculation unit **42** to the reference positional deviation amount calculation unit **43**.

The reference positional deviation amount calculation unit **43** executes the processing of Step S**12** to Step S**14** shown in FIG. **10**, whereby the reference amount of positional deviation $\Delta y1$ of the recording position of the first head module **28**A is calculated, as shown in FIGS. **7**C and **11** (Step S**30**). The calculation result of the reference amount of positional deviation $\Delta y1$ is output from the reference positional deviation amount calculation unit **43** to the positional deviation amount calculation unit **44**. With the above, the calculation processing (Step S**24**, see FIG. **15**) of the reference amount of positional deviation $\Delta y1$ is completed.

(Calculation Processing of Reference Amount of Positional Deviation $\Delta y2$)

Returning to FIG. **15**, after the calculation processing of the reference amount of positional deviation $\Delta y1$, the calculation processing of the reference amount of positional deviation $\Delta y2$ of the recording position of the second head module **28**B is started (Step S**32**). In the calculation processing of the reference amount of positional deviation $\Delta y2$, the processing of Step S**26** to Step S**30** shown in FIG. **16** is executed again. With this, after the calculation of the second density profile **53**B shown in FIG. **12**, the generation of the second density profile **53**B**1**, the calculation of the repetition period length W**2**, and the calculation of the second integrated density profile **56**B are performed, the reference amount of positional deviation $\Delta y2$ of the recording position of the second head module **28**B is calculated. The calculation result of the reference amount of positional deviation $\Delta y2$ is output to the positional deviation amount calculation unit **44**.

(Calculation Processing of Amount of Positional Deviation ΔY)

As shown in FIG. **13**, the positional deviation amount calculation unit **44** calculates the amount of positional deviation ΔY based on the difference between the reference amount of positional deviation $\Delta y1$ and the reference amount of positional deviation $\Delta y2$ (the difference between the peak position X_P corresponding to the first dot pattern **50**A and the peak position X_P corresponding to the second dot pattern **50**B) (Step S**33**, positional deviation amount calculation step). The calculation result of the amount of positional deviation ΔY is output from the positional deviation amount calculation unit **44** to the positional deviation correction processing unit **45**. With the above, the positional deviation amount measurement processing (Step S**20**, see FIG. **14**) is completed.

The amount of positional deviation ΔY of the recording position between the second and third head modules **28**B and **28**C can be measured in the same manner.

(Positional Deviation Correction Processing)

Returning to FIG. **14**, if a printing start operation is performed by an operating unit (not shown) or the like (Step S36), image data sent from the host computer **11** is stored in the image page memory **18** through the host I/F unit **17** (Step S37). Then, print data for single deposition based on image data is successively transferred to the head driver **23** under the control of the CPU **24**. At this time, positional deviation correction processing unit **45** controls the post-processing arithmetic unit **21** based on the detection result of the amount of positional deviation ΔY to perform the positional deviation correction processing for print data. With this, the positional deviation of the recording position between the first and second head modules **28**A and **28**B is corrected (Step S**38**).

The head driver **23** controls ink ejection of the nozzles **27** of the head modules **28**A to **28**C based on print data. Then, the ink droplets **36** are deposited by the head modules **28**A to **28**C while transporting the recording sheet **13** in the sub scanning direction by the transport mechanism **12**. With this, an image based on image data is recorded on the recording surface of the recording sheet **13** (Step S**39**).

When performing printing again based on another piece of image data (YES in Step S**40**), the processing of Step S**37** to Step S**39** described above is repeatedly executed.

At this time, when replacing the first and second head modules **28**A and **28**B, when a predetermined time has elapsed after the amount of positional deviation ΔY is measured, or when a predetermined number of sheets are printed, and when an instruction to re-measure the amount of positional deviation ΔY is received from the user, or the like, the measurement processing of the amount of positional deviation ΔY is executed again (YES in Step S**41**, Step S**42**). With this, the processing of Step S**21** to Step S**30** shown in FIGS. **15** and **16** described above is repeatedly executed, whereby a new amount of positional deviation ΔY is measured.

Hereinafter, the processing of the respective steps described above is repeatedly executed until printing in the printer **10** ends.

Functional Effects of Ink Jet Printer of First Embodiment

In this way, in this embodiment, since the first and second integrated density profiles **56**A and **56**B are calculated based on the read image of the test chart **31**, and the amount of positional deviation ΔY is measured based on the first and second integrated density profiles **56**A and **56**B, it is possible to measure the amount of positional deviation of the recording position between the head module at low cost and with high accuracy without using a high-resolution image sensor.

Ink Jet Printer of Second Embodiment

Next, a printer **70** according to a second embodiment of the invention will be described referring to FIG. **17**. In the above-described first embodiment, although the recording areas where the head modules **28**A to **28**C perform recording on the recording sheet **13** do not overlap one another, in the printer **70**, the recording areas of adjacent head modules overlap each other. The printer **70** basically has the same configuration as the printer **10** of the first embodiment, except that a recording head **72** different from the first embodiment is provided. For this reason, the parts having the same functions and configurations as those in the first embodiment are represented by the same reference numerals, and description thereof will not be repeated.

The recording head **72** includes three replaceable head modules of a first head module **73**A, a second head module **73**B, and a third head module **73**C, and a frame body **29**. The head modules **73**A to **73**C are arranged in zigzag in the main scanning direction. The end portions of two adjacent head modules among the head modules **73**A to **73**C overlap each other. The head modules **73**A to **73**C correspond to a first head module and a second head module of the invention. The recording head **72** may also include tow or, or four or more replaceable head modules of a first head module **73**A.

Part of nozzles **27***a* of the first head module **73**A and the second head module **73**B are arranged so as to overlap each other in the main scanning direction. Part of nozzles **27***a* of the second head module **73**B and the third head module **73**C are arranged so as to overlap each other in the main scanning direction. With this, the recording area of the first head module **73**A and the recording area of the second head module **73**B partially overlap each other, and the recording area of the second head module **73**B and the recording area of the third head module **73**C partially overlap each other. Hereinafter, the overlap area of the recording areas is referred to as an "overlap recording area", and a recording area other than the overlap recording area is referred to a "non-overlap recording area".

As shown in FIG. **18**, as in the first embodiment shown in FIG. **3**, the positional deviation of the recording position among the head modules **73**A to **73**C occurs due to the positional deviation of the head modules **73**A to **73**C, or flight deflection of the ink droplets **36** (not shown).

A measurement method of the amount of positional deviation ΔY of the recording position among the head modules **73**A to **73**C is basically the same as the measurement method described in the first embodiment, except that a test chart **75** (see FIG. **19**) different from that in the first embodiment is recorded on the recording sheet **13**.

As in the first embodiment, the test chart recording control unit **38** outputs test chart data **35** to the image page memory **18** and operates the image buffer memory write control unit **19**, the transfer control unit **22**, and the head driver **23** to execute recording of the test chart **75**. However, at this time, the test chart recording control unit **38** inhibits (stops) ejection of the ink droplets **36** from the nozzles **27***a*. That is, the test chart **75** is recorded in the non-overlap area only by the nozzles **27** of the head modules **73**A to **73**C.

As shown in FIG. **19**, the test chart **75** includes a first dot pattern group **76**A, a second dot pattern group **76**B, and a third dot pattern group (not shown) recorded only by the nozzles **27** of the head modules **73**A to **73**C. The first dot pattern group **76**A has, for example, 150 first dot patterns **77**A having a shape extended long in the main scanning direction at pattern intervals W**1** (repetition period) in the sub scanning direction.

The second dot pattern group **76**B has, for example, 150 second dot patterns **77**B having the same shape as the first dot patterns **77**A at the pattern intervals W**1** (repetition period) in the sub scanning direction. Each second dot pattern **50**B is recorded to be deviated from the first dot pattern **50**A by an amount according to the positional deviation between the first and second head modules **73**A and **73**B in the sub scanning direction.

The third dot pattern group has, for example, 150 third dot patterns (not shown) having the same shape as the first dot patterns **77**A at the pattern intervals W**1** in the sub scanning direction. The dot patterns **77**A and **77**B correspond to a first dot pattern and a second dot pattern of the invention.

In this way, the test chart **75** is the same as the test chart **31** of the first embodiment, except that the first and the second dot patterns **77**A and **77**B are different in length in the main scanning direction. Accordingly, as in first embodiment, the processing of Step S**21** to Step S**33** shown in FIGS. **15** and **16** is executed by the respective units of the CPU **24**, whereby it is possible to calculate the amount of positional deviation ΔY of the recording position between two head modules among the head modules **73**A to **73**C. It is also possible to correct the positional deviation based on the calculation result of the amount of positional deviation ΔY. With this, the same effects as the above-described first embodiment are obtained.

Ink Jet Printer of Third Embodiment

<Configuration of Ink Jet Printer>

Next, a printer **80** according to a third embodiment of the invention will be described referring to FIG. **20**. In the above-described second embodiment, the test chart **75** is recorded only by the nozzles **27** of the head modules **73**A to **73**C. In contrast, in the printer **80**, a test chart **81** is recorded in the overlap recording area of the recording sheet **13** using only the nozzles **27***a* of the head modules **73**A to **73**C, and the amount of positional deviation ΔY is measured based on the read image of the test chart **81**.

The printer **80** basically has the same configuration as the printer **10** of the first embodiment, except that a CPU **83** and a recording head **72** different from those in the first embodiment are provided. The recording head **72** of the printer **80** has the same configuration as the recording head **72** of the second embodiment. For this reason, the parts having the same functions and configurations as those in the first and second embodiments are represented by the same reference numerals, and description thereof will not be repeated.

<Configuration Relating to Measurement of Amount of Positional Deviation>

The CPU **83** reads and executes a program relating to measurement of the amount of positional deviation ΔY or positional deviation correction from the memory **34** to function as a test chart recording control unit (recording control unit) **85**, a density profile data calculation unit **86**, a complementary processing unit **87**, a repetition period calculation unit **88**, an integrated density profile calculation unit **89**, a positional deviation amount calculation unit **90**, and a positional deviation correction processing unit **45**.

(Recording of Test Chart)

Similarly to the test chart recording control unit **38** of the first embodiment, the test chart recording control unit **85** outputs test chart data **35** to the image page memory **18** and operates the image buffer memory write control unit **19**, the transfer control unit **22**, and the head driver **23** to execute recording of the test chart **81**. However, at this time, the test chart recording control unit **85** inhibits (stops) ejection of the ink droplets **36** from the nozzles **27**. That is, the test chart **81** is recorded in an overlap recording area (OLA) (see FIG. **21**) only by the nozzles **27***a* of the head modules **73**A to **73**C.

As shown in FIG. **21**, the test chart **81** includes first dot patterns **94**A which are recorded by the nozzles **27***a* of the first head module **73**A, second dot patterns **94**B which are recorded by the nozzles **27***a* of the second head module **73**B, and third dot patterns (not shown) which are recorded by the nozzles **27***a* of the third head module **73**C. The dot patterns **94**A and **94**B have a shape extended long in the main scanning direction and correspond to a first dot pattern and a second dot pattern of the invention. For example, 150 first and second dot patterns **94**A and **94**B are recorded at pattern intervals W**1** (repetition period) in the sub scanning direction. Simultaneously, the first and second dot patterns **94**A and **94**B are recorded alternately in the sub scanning direction. Though not shown, the same applies to the second dot patterns **94**B and the third dot patterns.

(Calculation of Density Profile)

As shown in FIGS. **22**A and **22**B, the density profile data calculation unit **86** analyzes read image data **32** of the test chart **81** acquired from the image scanner **16** to calculate a third density profile **96** representing change in density in the sub scanning direction of the overlap recording area OLA of the recording sheet **13**. In the third density profile **96**, the density at a position corresponding to each of the first and second dot patterns **94**A and **94**B becomes higher, and conversely, the density at a position corresponding to between the first and second dot patterns **94**A and **94**B becomes lower. As in the first embodiment, since the resolution of the image scanner **16** in the sub scanning direction is low, the resolution of the third density profile **96** in the sub scanning direction also becomes low. The density profile data calculation unit **86** outputs the third density profile **96** to the complementary processing unit **87**.

(Complementary Processing)

As shown in FIG. **22**C, the complementary processing unit **87** performs the same linear complementary processing as in the first embodiment for the third density profile **96** to enhance the resolution of the third density profile **96** in the sub scanning direction from 100 dpi to 10000 dpi. The resolution of the third density profile **96** is enhanced in the sub scanning direction, whereby it is possible to calculate the amount of positional deviation ΔY with higher accuracy. The complementary processing unit **40** outputs a resolution-enhanced third density profile **96***a* to the repetition period calculation unit **88**.

As shown in FIG. **23**A, the repetition period calculation unit **88** calculates a repetition period length W**3** representing a repetition period of change in density corresponding to the first and second dot patterns **94**A and **94**B adjacent to each other based on the third density profile **96**. Similarly to the calculation method of the first embodiment shown in FIGS. **8** and **9**, the repetition period length W**3** can be calculated by calculating a temporary integrated density profile in each temporary repetition period and comparing the maximum value of each temporary integrated density profile. The "maximum value" of each temporary integrated density profile is a total value of two peak values shown in FIG. **23**C. The repetition period calculation unit **88** outputs the calculation result of the repetition period length W**3** to the integrated density profile calculation unit **89** along with the third density profile **96***a*.

As shown in FIG. **23**B, the integrated density profile calculation unit **89** integrates and averages data of the third density profile **96***a* in each repetition period length W**3** to calculate a third integrated density profile **98**. The integrated density profile calculation unit **89** outputs the third integrated density profile **98** to the positional deviation amount calculation unit **90**.

As shown in FIG. **23**C, the positional deviation amount calculation unit **90** analyzes the third integrated density profile **98** to calculate the amount of positional deviation ΔY between the recording position of the first head module **73**A and the recording position of the second head module **73**B. Hereinafter, a calculation method of the amount of positional deviation ΔY based on the third integrated density profile **98** will be specifically described.

As shown in FIGS. **24** and **25**, the positional deviation amount calculation unit **90** determines a threshold value Th of data of the third integrated density profile **98** using Expression (2) described in the above-described first embodiment. Then, the positional deviation amount calculation unit **90** extracts data exceeding the threshold value Th among data of the third integrated density profile **98** (Step S**50**).

Next, the positional deviation amount calculation unit **90** obtains an average value of X values (integrated phase values: positions within the repetition period) exceeding the threshold value Th, sets data with the X value smaller than the average value as a "group **1**", and conversely, sets data greater than the average value as a "group **2**" (Step S**51**). In this embodiment, the group **1** is data corresponding to the first dot patterns **94**A, and the group **2** is data corresponding to the second dot patterns **94**B.

The positional deviation amount calculation unit **90** computes an approximate curve (for example, quadratic function: $y=ax^2+bx+c$, displayed by a solid line in FIG. **25**) for data of the group **1** and calculates a peak position X_{P1} of the approximate curve (Step S**52**). The peak position X_{P1} is calculated based on, for example, $X_{P1}=-b\div(2\times a)$.

The positional deviation amount calculation unit **90** computes the approximate curve for data of the group **2** and calculates a peak position X_{P2} of the approximate curve similarly to the calculation of the peak position X_{P1} (Step S**53**). The peak position X_{P2} is also calculated based on, for example, $X_{P2}=-b\ (2\times a)$.

Next, the positional deviation amount calculation unit **90** calculates the amount of positional deviation ΔY based on the peak position X_{P1}, the peak position X_{P2}, the resolution R_m of the image scanner **16**, and the resolution R_h after resolution enhancement using Expressions (5) and (6) described below (Step S**54**). That is, the amount of positional deviation ΔY is calculated based on the difference between the peak position X_{P1} corresponding to the first dot pattern **94**A and the peak position X_{P2} corresponding to the second dot pattern **94**B. The positional deviation amount calculation unit **90** outputs the calculation result of the amount of positional deviation ΔY to the positional deviation correction processing unit **45**. The amount of positional deviation ΔY is the amount of positional deviation of the recording position including the amount of deviation from a design position shown in FIG. **18**, the amount of deviation due to zigzag arrangement, and an error of the ink ejection timing set in each head module at the time of recording of the test chart.

$$(X_{P1}-X_{P2})\div R_h\times R_m\rightarrow p(\text{pixl/scanner resolution}) \tag{5}$$

$$p\div R_m\times 25400\rightarrow \Delta Y \tag{6}$$

Operation of Ink Jet Printer of Third Embodiment

Next, the operation of the printer **80** having the above-described configuration, in particular, measurement processing of the amount of positional deviation ΔY will be described. Image recording processing including positional deviation correction processing is the same as that in the first embodiment, and thus, description thereof will not be repeated. Here, a case of measuring the amount of positional deviation ΔY of the recording position between the first and second head modules **73**A and **73**B will be described.

As shown in FIG. **26**, when the printer **80** is powered on, when at least one of the first and second head modules **73**A and **73**B is newly mounted in the recording head **72**, or the like, the respective units **85** to **90** of the CPU **83** are operated to start the measurement processing of the amount of positional deviation ΔY (Step S**20**).

As in the first embodiment, print data for single deposition based on test chart data **35** is successively transferred to the head driver **23** under the control of the test chart recording control unit **85**. The head driver **23** controls ink ejection of the nozzles **27***a* of the head modules **73**A to **73**C based on print data. Then, the ink droplets **36** are deposited by the head modules **73**A to **73**C while transporting the recording sheet **13** in the sub scanning direction by the transport mechanism **12**, whereby the test chart **81** is recorded in the overlap recording area OLA (Step S**58**, recording step).

After the recording of the test chart **81**, as in the first embodiment, the test chart **81** is read by the image scanner **16**, and read image data **32** is output from the image scanner **16** to the density profile data calculation unit **86** (Step S**59**, reading step).

After the input of read image data **32**, the density profile data calculation unit **86** identifies two head modules as a target of measurement of the amount of positional deviation ΔY, that is, the first and second head modules **73**A and **73**B (Step S**60**).

Next, the density profile data calculation unit **86** analyzes read image data **32** to calculate the third density profile **96** shown in FIG. **22**B (Step S**61**, density profile calculation step). The third density profile **96** is output from the density profile data calculation unit **86** to the complementary processing unit **87**.

The complementary processing unit **87** performs linear complementary processing for the third density profile **96** to generate a resolution-enhanced third density profile **96***a* shown in FIG. **22**C (Step S**62**, complementary processing step). The third density profile **96***a* is output from the complementary processing unit **87** to the repetition period calculation unit **88**.

The repetition period calculation unit **88** executes the basically same processing as the processing of Step S**1** to Step S**9** shown in FIG. **8** to calculate the temporary integrated density profile in each temporary repetition period, and compares the magnitude of the maximum value (the total value of the group **1** and the group **2**) of each temporary integrated density profile. With this, the repetition period length W**3** shown in FIG. **23**A is calculated by the repetition period calculation unit **41** (Step S**63**, repetition period calculation step). The calculation result of the repetition period length W**3** is output from the repetition period calculation unit **88** to the integrated density profile calculation unit **89** along with the third density profile **96***a*.

As shown in FIG. **23**B, the integrated density profile calculation unit **89** integrates and averages the third density profile **96***a* in each repetition period length W**3** to calculate the third integrated density profile **98** (Step S**64**, integrated density profile calculation step). The third integrated density profile **98** is output from the integrated density profile calculation unit **89** to the positional deviation amount calculation unit **90**.

The positional deviation amount calculation unit **90** executes the processing of Step S**50** to Step S**54** shown in FIG. **24**. With this, as shown in FIGS. **23**C and **25**, the positional deviation amount calculation unit **90** calculates the amount of positional deviation ΔY of the recording position between the first and second head modules **73**A and **73**B based on the difference between the peak position X_{P1} and the peak position X_{P2} (Step S**65**). With the above, the positional deviation amount measurement processing is completed.

Functional Effects of Ink Jet Printer of Third Embodiment

In this way, in the third embodiment of the invention, the test chart **81** recorded in the overlap recording area OLA is analyzed, whereby it is possible to directly calculate the amount of positional deviation ΔY without calculating the reference amounts of positional deviation Δy**1** and Δy**2** of the head modules as in the first embodiment. With this, it is possible to reduce the time necessary for calculating the amount of positional deviation ΔY. As in the first embodiment, it is possible to measure the amount of positional deviation of the recording position between the head modules at low cost and with high accuracy without using a high-resolution image sensor.

[Configuration Example of Another Ink Jet Printer]

Next, a configuration example of a printer **100** as an example of the printer **10** shown in FIG. **1** will be described.

As shown in FIG. **27**, the printer **100** is a direct drawing ink jet printer which deposits ink of a plurality of colors on a recording sheet **13** retained by a drawing drum **170** from a recording head **250** (constituted by ink jet heads **172**M, **172**K, **172**C, and **172**Y of CMYK) to form a desired color image. The printer **100** applies a two-liquid reaction (aggregation) system in which a processing liquid (in this case, an aggregation processing liquid) is applied on the recording sheet **13** before ink deposition, and the processing liquid reacts with the ink liquid to perform image formation on the recording sheet **13**.

The printer **100** primarily includes a sheet feed unit **112**, a processing liquid application unit **114**, a recording unit **116**, a drying unit **118**, a fixing unit **120**, and a sheet discharge unit **122**.

(Sheet Feed Unit)

In the sheet feed unit **112**, recording sheets **13** which are paper sheets are stacked. The recording sheets **13** are fed from a sheet feed tray **150** of the sheet feed unit **112** to the processing liquid application unit **114** one by one. Although paper sheets (cut paper) are used as the recording sheets **13**, a continuous sheet (roll paper) may be cut to a necessary size and fed.

(Processing Liquid Application Unit)

The processing liquid application unit **114** is a mechanism which applies a processing liquid on the surface of the recording sheet **13**. The processing liquid includes a coloring material aggregating agent which aggregates a coloring material (in this example, a pigment) in ink applied by the recording unit **116**, and the processing liquid comes into contact with ink, thereby promoting separation of the coloring material and the solvent in ink.

The processing liquid application unit **114** includes a sheet feed cylinder **152**, a processing liquid drum **154**, and a processing liquid coating device **156**. The processing liquid drum **154** includes a claw-shaped retaining unit (gripper) **155** on the outer peripheral surface, and the recording sheet **13** is sandwiched between the claw of the retaining unit **155** and the peripheral surface of the processing liquid drum **154** such that the leading end of the recording sheet **13** can be retained. A suction hole may be provided in the outer peripheral surface of the processing liquid drum **154**, and a suction unit performing suction from the suction hole may be connected. With this, the recording sheet **13** can be retained tightly on the peripheral surface of the processing liquid drum **154**.

The processing liquid coating device **156** is arranged to face the peripheral surface of the processing liquid drum **154**. The processing liquid coating device **156** is constituted by a processing liquid container which stores the processing liquid, an annex roller which is partially immersed into the processing liquid of the processing liquid container, and a rubber roller which is brought into press contact with the annex roller and the recording sheet **13** on the processing liquid drum **154** to transfer the processing liquid after measurement to the recording sheet **13**. According to the processing liquid coating device **156**, it is possible to coat the surface of the recording sheet **13** with the processing liquid while measuring the processing liquid. In this embodiment, although a configuration in which a coating system using a roller is applied has been illustrated, the invention is not limited thereto, and for example, various systems, such as a spray system and an ink jet system, may be applied.

The recording sheet **13** applied with the processing liquid is delivered from the processing liquid drum **154** to a drawing drum **170** of the recording unit **116** through an intermediate transport unit **126**.

(Recording Unit)

The recording unit **116** includes a drawing drum **170**, a sheet pressing roller **174**, and an ink jet head **250** (ink jet heads **172**M, **172**K, **172**C, and **172**Y). Similarly to the processing liquid drum **154**, the drawing drum **170** includes claw-shaped retaining unit (gripper) **171** on the outer peripheral surface.

Each of the ink jet heads **172**M, **172**K, **172**C, and **172**Y is a full line ink jet system ink jet head which has a length corresponding to the maximum width of an image forming area in the recording sheet **13**, and a nozzle array having a plurality of nozzles for ink ejection over the full width of the image forming area is formed on the ink ejection surface. The ink jet heads **172**M, **172**K, **172**C, and **172**Y are arranged so as to extend in a direction (first direction) orthogonal to the transport direction (the rotation direction of the drawing drum **170**, second direction) of the recording sheet **13**.

The droplets of corresponding color ink are ejected from the ink jet heads **172**M, **172**K, **172**C, and **172**Y of the ink jet head **250** arranged to face the surface of the recording sheet **13** toward the surface of the recording sheet **13** retained tightly on the drawing drum **170**, ink comes into contact with the processing liquid applied to the recording surface applied in advance by the processing liquid application unit **114**, the coloring materials (pigments) dispersed in ink are aggregated, and a coloring material aggregate is formed. With this, coloring material bleeding on the recording sheet **13** is prevented, and an image is formed on the surface of the recording sheet **13**.

That is, the recording sheet **13** is transported by the drawing drum **170** at a given speed and an operation of relatively moving the recording sheet **13** and the ink jet heads **172**M, **172**K, **172**C, and **172**Y with respect to the transport direction is performed only once (that is, single sub scanning is performed), whereby an image can be recorded in the image forming area on the surface of the recording sheet **13**.

The recording sheet **13** with the image formed thereon is delivered from the drawing drum **170** to a drying drum **176** of the drying unit **118** through an intermediate transport unit **128**.

(Drying Unit)

The drying unit **118** is a mechanism which dries moisture contained in the solvent separated by the coloring material aggregation, and includes a drying drum **176** and a solvent drying device **178**. Similarly to the processing liquid drum **154**, the drying drum **176** includes a claw-shaped retaining unit (gripper) **177** on the outer peripheral surface, and the leading end of the recording sheet **13** can be retained by the retaining unit **177**.

The solvent drying device **178** is arranged at a position facing the outer peripheral surface of the drying drum **176**, and is constituted by a plurality of halogen heaters **180**, and hot air injection nozzles **182** arranged between the halogen heaters **180**. The recording sheet **13** subjected to drying processing in the drying unit **118** is delivered from the drying drum **176** to a fixing drum **184** of the fixing unit **120** through an intermediate transport unit **130**.

(Fixing Unit)

The fixing unit **120** is constituted by a fixing drum **184**, halogen heaters **186**, a fixing roller **188**, and an inline sensor **190**. Similarly to the processing liquid drum **154**, the fixing drum **184** includes a claw-shaped retaining unit (gripper) **185** on the outer peripheral surface, and the leading end of the recording sheet **13** can be retained by the retaining unit **185**.

With the rotation of the fixing drum **184**, preheating by the halogen heaters **186**, fixing processing by the fixing roller **188**, and examination by the inline sensor **190** are performed for the recording surface (both surfaces) of the recording sheet **13**.

The fixing roller **188** is a roller member which heats and presses dried ink to weld self-dispersive polymer particulates in ink and forms a film of ink, and is configured to heat and press the recording sheet **13**. Specifically, the fixing roller **188** is arranged so as to come into press contact with the fixing drum **184**, and constitutes a nip roller with the fixing drum **184**. The recording sheet **13** is sandwiched between the fixing roller **188** and the fixing drum **184** and is nipped at a predetermined nip pressure, and fixing processing is performed.

The fixing roller **188** is constituted by a heating roller in which a halogen lamp or the like is incorporated, and is controlled at a predetermined temperature.

The inline sensor (reading unit) **190** is a unit for reading an image formed on the recording sheet **13** and detecting image density, image defect, or the like, and a CCD line sensor or the like is applied. The inline sensor **190** is basically the same as the image scanner **16** described above.

According to the fixing unit **120**, since latex particles in a thin image layer formed by the drying unit **118** are heated and pressed by the fixing roller **188** and melted, ink can be fixed on the recording sheet **13**. The surface temperature of the fixing drum **184** is set to be equal or higher 50° C.

Instead of ink containing a high boiling point solvent and polymer particulates (thermoplastic resin particles), ink which contains a monomer component capable of being polymerization-curable with UV exposure may be used. In this case, the printer **100** includes a UV exposure unit which exposes UV light to ink on the recording sheet **13**, instead of a hot pressing fixing unit (fixing roller **188**) using a heating roller. In this case, when ink containing active ray-curable resin, such as UV-curing resin, is used, instead of the fixing roller **188** for heating and fixing, a unit irradiating active rays, such as a UV lamp or an ultraviolet laser diode (LD) array, is provided.

(Sheet Discharge Unit)

The sheet discharge unit **122** is provided after the fixing unit **120**. The sheet discharge unit **122** includes a discharge tray **192**, and a transfer cylinder **194**, a transport belt **196**, and a tension roller **198** are provided between the discharge tray **192** and the fixing drum **184** of the fixing unit **120**. The recording sheet **13** is transferred to the transport belt **196** by the transfer cylinder **194** and is discharged to the discharge tray **192**. Though details of a sheet transport mechanism using the transport belt **196** are not shown, the recording sheet **13** after printing is carried above the discharge tray **192** by the rotation of the transport belt **196** in a state where the leading end of the sheet is retained by a gripper of a bar (not shown) across the endless transport belt **196**.

Though not shown, the printer **100** of this example includes, in addition to the above-described configuration, an ink storage/loading unit which supplies ink to the ink jet heads **172**M, **172**K, **172**C, and **172**Y, a unit supplying a processing liquid to the processing liquid application unit **114**, a head maintenance unit which performs cleaning (wiping of the nozzle surface, purging, nozzle suction, and the like) of the ink jet heads **172**M, **172**K, **172**C, and **172**Y, a position detection sensor which detects the position of the recording sheet **13** on a sheet transport path, a temperature sensor which detects the temperature of each unit of the device, and the like.

[Structure of Ink Jet Head]

Next, the structure of each of the ink jet heads **172**M, **172**K, **172**C, and **172**Y in the recording unit **116** will be described. Since the ink jet heads **172**M, **172**K, **172**C, and **172**Y corresponding to the respective colors have the common structure, hereinafter, these ink jet heads will be representatively described as the ink jet head **250**.

As shown in FIG. **28**, the ink jet head **250** has a structure in which a plurality of ink chamber units (liquid droplet ejection elements as a recording element unit) **253** having a nozzle **251** as an ink ejection port, a pressure chamber **252** communicating with the nozzle **251**, and a supply port **254** communicating a common flow channel (not shown) with the pressure chamber **252**, and the like are arranged in a matrix. With this, the ink jet head **250** attains the high density of a substantial nozzle interval (a projection nozzle pitch represented by reference numeral Pn) which is projected so as to align in the main scanning direction as the longitudinal direction of the ink jet head **250**.

The pressure chamber **252** communicating with the nozzle **251** schematically has a square planar shape, the nozzle **251** is provided at one of both corners on the diagonal, and the supply port **254** is provided at the other corner. The shape of the pressure chamber **252** is not limited to this example, and may have various planar shapes, such as a quadrangle (rhomboid, rectangle, or the like), a pentagon, a hexagon, other polygons, a circle, and an ellipse.

The ink chamber units **253** having the nozzle **251**, the pressure chamber **252**, and the like are arranged in a matrix in a given arrangement pattern in a row direction along the main scanning direction and an oblique column direction (represented by reference numeral Sa) not orthogonal to the main scanning direction at a given angle θ ($0° < \theta < 90°$), whereby the high-density nozzle head of this example is implemented.

With the structure in which a plurality of ink chamber units **253** are arranged at given pitches g in a direction at a certain angle θ with respect to the main scanning direction, the projection nozzle pitch Pn projected so as to align in the main scanning direction becomes $g \times \cos\theta$. For this reason, the main scanning direction can be handled equivalent to the nozzles **251** linearly arranged at given pitches Pn. With this configuration, a nozzle array projected so as to align in the main scanning direction can implement high-density arrangement of 1200 per inch (1200 nozzles/inch).

As shown in FIG. **29**, the ink jet head **250** has a structure in which a nozzle plate **251**A in which the nozzle **251** is formed and a flow channel plate **252**P in which the pressure chamber **252** and a flow channel, such as the common flow channel **255**, are formed are laminated and bonded together.

The flow channel plate **252**P is a flow channel forming member which constitutes the sidewall portion of the pressure chamber **252** and forms a supply port **254** as a throttle portion (narrowest portion) of an individual supply path guiding ink from the common flow channel **255** to the pressure chamber **252**. Though schematically shown in FIG. **29** for convenience of description, the flow channel plate **252**P has a structure in which one substrate is provided or a plurality of substrates are laminated.

The nozzle plate **251**A and the flow channel plate **252**P can be machined to a required shape by a semiconductor manufacturing process using silicon as a material.

The common flow channel **255** communicates with an ink tank (not shown) as an ink supply source, and ink supplied from the ink tank is supplied to each pressure chamber **252** through the common flow channel **255**.

A piezoelectric actuator **258** including an individual electrode **257** is bonded to a vibration plate **256** constituting the surface (in FIG. **29**, a top surface) of a part of the pressure chamber **252**. The vibration plate **256** of this example is made of silicon (Si) with a nickel (Ni) conductive layer which functions as a common electrode **259** corresponding to a lower electrode of the piezoelectric actuator **258**, and is also used as a common electrode of the piezoelectric actuator **258** arranged corresponding to each pressure chamber **252**. An aspect in which a vibration plate is formed of a nonconductive material, such as resin, may be made, and in this case, a common electrode layer made of a conductive material, such as metal, is formed on the surface of a vibration plate member. A vibration plate which is also used as a common electrode may be made of a metal (conductive material), such as stainless steel (SUS).

With the application of a drive voltage to the individual electrode **257**, the piezoelectric actuator **258** is deformed to change the volume of the pressure chamber **252**, and ink is ejected from the nozzle **251** with accompanying change in pressure. After ink ejection, when the piezoelectric actuator **258** returns to the original state, new ink refills the pressure chamber **252** from the common flow channel **255** through the supply port **254**.

In this example, although the printer **100** to which an impression cylinder transport system is applied has been illustrated, a transport system of the recording sheet **13** is not limited to the impression cylinder transport system, and a belt transport system in which the recording sheet **13** is transported in a state adsorbed and retained on a transport belt, or other transport systems can be appropriately selected.

An arrangement form of the nozzles **251** is not limited to the example shown in the drawing, and various nozzle arrangement structures can be applied. For example, polygonal nozzle arrangement, such as single-line linear arrangement, V-shaped nozzle arrangement, or zigzag arrangement (W-shaped arrangement) with V-shaped arrangement as a repetition unit, can be used.

Others

In the respective embodiments described above, although the amount of positional deviation ΔY of the recording position between adjacent head modules is calculated, the amount of positional deviation ΔY of the recording position between arbitrary head modules not adjacent to each other can be calculated using the same method. When the interval in the main scanning direction between the head modules as a target of measurement of the amount of positional deviation is wider, the tilt (rotation displacement of the recording head **72** with a direction perpendicular to the surface of the recording sheet **13**) of the recording head **72**, an error of the transport speed of the recording sheet **13**, deformation of the recording sheet **13**, an error of reading of the image scanner **16**, or the like affects the measurement result of the amount of positional deviation. For this reason, adjacent head modules are selected as a target of measurement of the amount of positional deviation ΔY, whereby it is possible to measure the amount of positional deviation ΔY with higher accuracy.

In the respective embodiments described above, although the linear complementary processing is performed for each density profile by the complementary processing unit **40** or **87**, a complementary method is not particularly limited as long as the resolution of each density profile can be enhanced in the sub scanning direction. A calculation method of the repetition period length W**2** or W**3** of each density profile is not particularly limited to the method shown in FIGS. **8** and **9** described above, and various known methods may be used.

In the respective embodiments described above, although the pattern interval **W1** (period length) is arbitrarily set, it is preferable that the pattern interval **W1** is a non-integer multiple of resolution of the image sensor of the image scanner **16** in the sub scanning direction. With this, since the reading position of the image sensor for each dot pattern arranged in the sub scanning direction is gradually deviated, for example, data at various measurement points in the sub scanning direction in the first density profile **53**A of FIG. **6**B is obtained. As a result, since a more accurate waveform of the first integrated density profile **56**A shown in FIG. **7**B is obtained, it is possible to accurately determine the peak position.

In the respective embodiments described above, although the first to third density profiles **53**A, **53**B, and **96** are integrated and averaged in each repetition period length **W2** or **W3** to calculate the first to third integrated density profiles **56**A, **56**B, and **98**, the density profiles **53**A, **53**B, and **96** may be integrated in each repetition period length **W2** or **W3** to calculate the first to third integrated density profiles without performing average processing.

In the respective embodiments described above, although 150 dot patterns are formed in the sub scanning direction, the number of dot patterns may be appropriately increased or decreased. When the number of dot patterns is great, the number of pieces of data of each density profile increases; thus, it is possible to measure the amount of positional deviation ΔY with higher accuracy.

Although the recording head of the embodiments described above perform recording of four colors of CMYK, colors to be recorded are not particularly limited. Furthermore, the invention can be applied to an ink jet printer which includes, for example, a shuttle head type recording head, in which a recording head is moved with respect to a recording sheet, instead of moving a recording sheet with respect to a fixed recording head.

In the respective embodiments described above, although an example where the invention is applied to an ink jet printer for graphic printing has been described, the application range of the invention is not limited to this example. For example, the invention can be widely applied to ink jet printers which draw various shapes or patterns using liquid functional materials, such as a wiring drawing device which draws wiring patterns of electronic circuits, manufacturing devices of various devices, a resist printing device which uses a resin liquid as a function liquid for ejection, a color filter manufacturing device, and a microstructure forming device which forms microstructures using a material for material deposition.

In the respective embodiments described above, although an example where an ink jet printer is provided as an image-recording device of the invention has been described, the invention can be applied to various image-recording devices, such as a thermal transfer recording device which has a plurality of recording heads each having thermal elements as recording elements, and an LED electrophotographic printer which has a plurality of recording heads having LED elements as recording elements.

What is claimed is:

1. A method for measuring an amount of positional deviation between recording positions of a plurality of head modules, the method comprising:

a recording step of, while relatively moving a recording head with a plurality of head modules each having a plurality of recording elements arranged in a first direction and a recording medium in a second direction orthogonal to the first direction, recording dot patterns having a shape extended in the first direction on the recording medium at intervals determined in advance in the second direction using a first head module and a second head module among the plurality of head modules;

a reading step of optically reading the dot patterns recorded on the recording medium in the recording step;

a density profile calculation step of calculating a density profile associated with the first head module representing change in density in the second direction of a read image of the dot patterns read in the reading step;

a repetition period calculation step of calculating a repetition period of a waveform corresponding to each dot pattern in the density profile based on a calculation result in the density profile calculation step;

an integrated density profile calculation step of integrating data of the density profile based on a calculation result of the repetition period calculation step in each repetition period to calculate an integrated density profile associated with the first head module; and

a positional deviation amount calculation step of obtaining a peak position of a waveform corresponding to each dot pattern in the integrated density profile based on a calculation result of the integrated density profile calculation step and calculating the amount of positional deviation in the second direction between a recording position of the first head module and a recording position of the second head module based on the peak position and another peak position associated with the second head module.

2. The method for measuring the amount of positional deviation according to claim **1**,

wherein, in the density profile calculation step, a first density profile corresponding to a first dot pattern recorded by the first head module and a second density profile corresponding to a second dot pattern recorded by the second head module are calculated as the density profile,

in the repetition period calculation step, a first repetition period of a waveform corresponding to the first dot pattern and a second repetition period representing a repetition period of a waveform corresponding to the second dot pattern are calculated as the repetition period based on the first and second density profiles,

in the integrated density profile calculation step, a first integrated density profile obtained by integrating data of the first density profile in each first repetition period and second integrated density profile obtained by integrating data of the second density profile in each second repetition period are calculated as the integrated density profile, and

in the positional deviation amount calculation step, a first peak position of a waveform corresponding to the first dot pattern in the first integrated density profile and a second peak position of a waveform corresponding to the second dot pattern in the second integrated density profile are obtained, and the amount of positional deviation is calculated based on the difference between the first peak position and the second peak position.

3. The method for measuring the amount of positional deviation according to claim **2**,

wherein the first head module and the second head module are connected to each other in the first direction.

4. The method for measuring the amount of positional deviation according to claim **3**,

wherein, in an overlap recording area where recording areas on the recording medium of the first and second head modules partially overlap each other,

in the recording step, the first dot pattern and the second dot pattern are recorded by the recording elements of the first and second head modules which perform recording in a recording area other than the overlap area.

5. The method for measuring the amount of positional deviation according to claim **4**,

wherein the repetition period calculation step has

a temporary integrated density profile calculation step of integrating data of the density profile in each temporary repetition period to calculate a temporary integrated density profile,

a repetition step of, while changing the temporary repetition period, repeatedly executing the temporary integrated density profile calculation step to calculate the temporary integrated density profile in each temporary repetition period, and

a determination step of comparing a maximum value of the temporary integrated density profile in each temporary repetition period and determining the temporary repetition period with the greatest maximum value as the repetition period.

6. The method for measuring the amount of positional deviation according to claim **3**,

wherein the repetition period calculation step has

a temporary integrated density profile calculation step of integrating data of the density profile in each temporary repetition period to calculate a temporary integrated density profile,

a repetition step of, while changing the temporary repetition period, repeatedly executing the temporary integrated density profile calculation step to calculate the temporary integrated density profile in each temporary repetition period, and

a determination step of comparing a maximum value of the temporary integrated density profile in each temporary repetition period and determining the temporary repetition period with the greatest maximum value as the repetition period.

7. The method for measuring the amount of positional deviation according to claim **3**, further comprising:

a complementary processing step of performing complementary processing on a density profile calculated in the density profile calculation step to enhance resolution of the density profile in the second direction,

wherein, in the repetition period calculation step, a repetition period is calculated based on a density profile subjected to the complementary processing.

8. The method for measuring the amount of positional deviation according to claim **2**,

wherein the repetition period calculation step has

a temporary integrated density profile calculation step of integrating data of the density profile in each temporary repetition period to calculate a temporary integrated density profile,

a repetition step of, while changing the temporary repetition period, repeatedly executing the temporary integrated density profile calculation step to calculate the temporary integrated density profile in each temporary repetition period, and

a determination step of comparing a maximum value of the temporary integrated density profile in each temporary repetition period and determining the temporary repetition period with the greatest maximum value as the repetition period.

9. The method for measuring the amount of positional deviation according to claim **2**, further comprising:

a complementary processing step of performing complementary processing on a density profile calculated in the density profile calculation step to enhance resolution of the density profile in the second direction,

wherein, in the repetition period calculation step, a repetition period is calculated based on a density profile subjected to the complementary processing.

10. The method for measuring the amount of positional deviation according to claim **2**,

wherein the first direction is a width direction of the recording medium.

11. The method for measuring the amount of positional deviation according to claim **1**,

wherein, in an overlap recording area where recording areas on the recording medium of the first and second head modules partially overlap each other,

in the recording step, a first dot pattern and a second dot pattern are individually recorded alternately at intervals determined in advance in the second direction as the dot patterns using the recording elements of the first and second head modules which perform recording in the overlap recording area,

in the density profile calculation step, a third density profile corresponding to the first dot pattern and the second dot pattern is calculated as the density profile,

in the repetition period calculation step, a third repetition period representing a repetition period of a waveform corresponding to the first and second dot patterns in the third density profile is calculated,

in the integrated density profile calculation step, a third integrated density profile obtained by integrating data of the third density profile in each third repetition period is calculated as the integrated density profile, and

in the positional deviation amount calculation step, a first peak position of a waveform corresponding to the first dot pattern and a second peak position of a waveform corresponding to the second dot pattern in the third integrated density profile are obtained, and the amount of positional deviation is calculated based on the difference between the first peak position and the second peak position.

12. The method for measuring the amount of positional deviation according to claim **11**,

wherein the repetition period calculation step has

a temporary integrated density profile calculation step of integrating data of the density profile in each temporary repetition period to calculate a temporary integrated density profile,

a repetition step of, while changing the temporary repetition period, repeatedly executing the temporary integrated density profile calculation step to calculate the temporary integrated density profile in each temporary repetition period, and

a determination step of comparing a maximum value of the temporary integrated density profile in each temporary repetition period and determining the temporary repetition period with the greatest maximum value as the repetition period.

13. The method for measuring the amount of positional deviation according to claim **11**, further comprising:

a complementary processing step of performing complementary processing on a density profile calculated in the density profile calculation step to enhance resolution of the density profile in the second direction,

wherein, in the repetition period calculation step, a repetition period is calculated based on a density profile subjected to the complementary processing.

14. The method for measuring the amount of positional deviation according to claim **1**,

wherein the repetition period calculation step has

a temporary integrated density profile calculation step of integrating data of the density profile in each temporary repetition period to calculate a temporary integrated density profile,

a repetition step of, while changing the temporary repetition period, repeatedly executing the temporary integrated density profile calculation step to calculate the temporary integrated density profile in each temporary repetition period, and

a determination step of comparing a maximum value of the temporary integrated density profile in each temporary repetition period and determining the temporary repetition period with the greatest maximum value as the repetition period.

15. The method for measuring the amount of positional deviation according to claim **1**, further comprising:

a complementary processing step of performing complementary processing on a density profile calculated in the density profile calculation step to enhance resolution of the density profile in the second direction,

wherein, in the repetition period calculation step, a repetition period is calculated based on a density profile subjected to the complementary processing.

16. The method for measuring the amount of positional deviation according to claim **1**,

wherein the first direction is a width direction of the recording medium.

17. The method for measuring the amount of positional deviation according to claim **1**,

wherein the recording head is an ink jet head.

18. An image-recording device for using the method for measuring the amount of positional deviation according to claim **1**, the image-recording device comprising:

a recording head with a plurality of head modules each having a plurality of recording elements arranged in a first direction;

a relative moving unit which relatively moves the recording head and a recording medium in a second direction orthogonal to the first direction;

a recording control unit which controls the recording head and the relative moving unit such that dot patterns having a shape extended in the first direction are recorded on the recording medium at intervals determined in advance in the second direction using a first head module and a second head module among the plurality of head modules;

a reading unit which optically reads the dot patterns recorded on the recording medium using the first head module and the second head module;

a density profile calculation unit which calculates a density profile representing change in density in the second direction of a read image of the dot patterns read by the reading unit;

a repetition period calculation unit which calculates a repetition period corresponding to each dot pattern in the density profile based on a calculation result of the density profile calculation unit;

an integrated density profile calculation unit which integrates data of the density profile based on a calculation result of the repetition period calculation unit in each repetition period to calculate an integrated density profile; and

a positional deviation amount calculation unit which obtains a peak position of a waveform corresponding to each dot pattern in the integrated density profile based on a calculation result of the integrated density profile calculation unit and calculates the amount of positional deviation in the second direction between a recording position of the first head module and a recording position of the second head module based on the peak position.

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